Teacher's Science Fair Guide to

THE ENGINEERING DESIGN PROCESS

In Lesson Plan Format

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TEACHER'S SCIENCE FAIR GUIDE TO THE ENGINEERING DESIGN PROCESSS

IN INQUIRY-BASED LESSON PLAN FORMAT

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M-ZAN SOLUTIONS INC
Evanston, IL

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Dedication
It is my pleasure to dedicate this book to my loving, supportive family - my children Mark and Marla, daughter-in-law Angela, son-in-law Mike, and grandchildren, Zack, Noah and Alexa.

Acknowledgments
I wish to express my appreciation to my cousin, Marsha Portnoy, who is always there to edit my works. To the teachers and students who have given inspiration and suggestions.

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TEACHER'S GUIDE

Introduction

Welcome to *Teacher's Science Fair Guide to the Engineering Design Process*. Before we get started, I want to share some thoughts and information that will be helpful to you. Teaching how to do an engineering science fair project can seem like an overwhelming experience for both the teacher and students.

Teaching how to do an engineering science fair project can seem like an overwhelming experience for both the teacher and students.

Treat this book like an encyclopedia. Pick and choose the lesson plans according to your school's requirements.

The purpose of this book is to provide tools to…

1. Eliminate your stress and time constraints, along with addressing students' difficulties with creating effective engineering science fair projects.

2. Provide a teacher's guide that unravels all the steps of creating a successful science fair project.

3. Teach the 8 steps of the engineering design process.

4. Lead guided, inquiry-based, investigatory lesson plans that have your students thinking like scientists.

5. Engage your students in a critical thinking process that develops their decision-making abilities.

6. Provide handouts and guideline sheets so you do not have to create your own.

7. Provide alternative ways for students to show the results of their investigation.

8. Help teachers who have never taught an inquiry-based investigation for engineering science fair projects or have never run a science fair.

9. Give guidance to 5th grade through high school teachers.

From feedback we have received from parents, teachers and kids, many students are at a loss as to how to even begin their science fair project, let alone how to complete one. Often times there is confusion about the steps to take to do an engineering design process science fair project opposed to one where experiments are performed. These are the reasons students procrastinate until the last minute, panic, and coerce one of their parents to get involved …who wind up doing their project! Sound familiar?

- The structure we recommend will help reduce the outcome of these stressors.
- Science Fair Projects are a powerful venue to achieve National Science Education Standards related to scientific inquiry.
- Students will learn a process that they can apply to other school work as well as their daily lives.
- Students will work on an engineering area of science that is of interest to them.
- Students will improve and expand their math skills by analyzing data and creating graphs.
- Students will improve reading comprehension. They will develop critical thinking and writing skills by doing background research and writing a project research paper.
- Students will expand their vocabularies.
- Students will learn to manage their time more effectively with a unique timeline and process.
- Students will work in teams like real engineers.

How to Navigate the PDF File

PDF documents have hyperlinks to the contents in the same document. When you click on a link that goes from one page to another page in the document and want to get back to the page where you clicked on the link, here is what you do: on your keyboard first hold down the Alt key and then the left arrow key while still holding the Alt key. I find that if you hold them down at the time, it doesn't work.

Resources and Thoughts

The purpose of the first six lessons is to set the stage and provide excellent tools before your students begin their projects.

Engineering science fair projects can become expensive. You are welcome to download the free eBook that I wrote, *Proven Ways to Fund Classroom Science Fair Projects*. It gives proven ways to raise money for science supplies. Ask a parent or the President of your school's association to organize and run the event(s). They will need to include the principal when they plan the fundraisers. My granddaughter's elementary school raised $23,000 by sponsoring a run/walk event in a morning! They do not live in a wealthy area either! There is also a website where individuals, classrooms or schools can request donations through a .org organization. In this brief eBook you will find easy to follow suggestions.

One more thing… I do not believe in giving tests to students, because they only test the ability of the teacher to teach. Therefore, there are no recommended tests included in the lesson plans. When you follow the inquiry-based method of teaching, you will find that your students will integrate their learnings and naturally apply that knowledge to various parts of their lives and other school subjects.

How to Use This Book

Step 1: Leisurely read the book from beginning to end. This will give you the whole picture of the process.

Step 2: Before You Begin Working with Your Students

A. Read the Teachers Role in Inquiry-Based Learning and the Students Role in Inquiry-Based Learning. These handy charts are excellent guidelines.

B. The bonus book has morning and afternoon five-minute activities to help build each student's confidence.

C. Decide whether you are going to have the class do one project or divide the students into small teams.

   The lesson plans in this book are designed for students working in teams. For the first few lesson plans the students will be put into different groups. Once the students choose the problem they want to solve, they will work in teams according to their interest.

   Advantages to breaking students into teams according to their interest:

   - You have fewer projects to oversee.
   - Students learn how to work on a team like real engineers.
   - Individual students do not feel the pressure of doing all the work.

   Disadvantage:

   It is more difficult to assess individual contributions. However, I really believe you will be able to know who is doing the work during the classroom participation sessions.

Step 3. Scheduling Your Lessons

- Setting Students' Assignment Expectations

  The lessons are broken into manageable bite size chunks to not to cause anxiety for both you and the students. This also gives you time to coach your students step-by-step.

- Schedule the dates you are going to begin and end the science fair program.

What to consider:

- An excellent science fair project takes between 2 to 3 months.
- The final report, making a display board, classroom presentation (optional), and science expo can take up to 3 weeks.
- Check with other teachers to see if they have long-term assignments planned. Coordinate your schedules. That way the students don't feel overburdened.
- If you live in the Northern Hemisphere, finish your lessons before the end of March so you can schedule the Science Fair in the first 2 weeks of April. This will allow students to participate in regional or district fairs that usually take place at that time.
- Use the Lesson Plan Teaching Schedule worksheet along with the Lesson Plans, student's Timeline and Student's Guide (included in this Book) to schedule your lessons. There are some sections you may only want the students to read and not discuss.
- Schedule your lesson plans in your daily planner.

Step 4: Talk with your school's webmaster and ask him or her to create a blog page for this project. Here you will be able to post lesson plan schedules, project resources, safety guidelines, other pertinent information and downloads for parents.

Step 5: Print the following pages

- **Parent's Guide**. You are going to need parental support because the students will be completing many of the steps at home. You may also need some financial support from them. Therefore, include the parents ASAP.
  - Call parents who have been helpful in the past and recruit one parent for each of the teams to act as a coach. I recommend 3 to 5 students per team, depending on age and ability.

    - Printables for Parents
        - Make a packet for the parents. Everything you put in the packet can also be place on the website where the parents can download the pages. Include a parent's letter. In it refer them to the science fair web page where they will be able to find your schedule, safety rules and information.

        - Also include the How Parents Can Help at Each Step chart and a copy of your classroom's **Lesson Plan Schedule** (what you are going to teach) a week before you present the 1st science fair lesson to your students. If possible, set the date for the teacher-parent meeting the evening of the day that you presented the first introductory lesson to your students.

- Printables for Students
    - Located in the Student's Appendix section of this book.

    - Print one for each student's team. They will be place it in each of their Design Notebooks after an activity is completed.

    - After each section of the Student's Guide information pages is an Outcomes Checklist. Print one per student / team.

- Printables for Teachers. Make a copy of your school's Science Fair Rules and print them for the parents and students or put them on your web page.

Step 6: Choose a format for source recitations in the research paper. Check the rules of your school, city, state and ISEF.

Optional Step A: If you are going to have a Science Fair Expo in your room or school, make necessary arrangements. Information and printables are in the Teacher's Appendix to help you get organized.

Optional Step B: Students have different primary learning modalities. Print the list.

Find out what's your modality because you may be teaching in your modality and not including the needs of some of your students. I highly recommend this to teachers and parents. I took this online test and it was 100% accurate. Take an online learning profile here.

Definition of Terms

The Engineering Design Process is an 8-step process. All steps are explained within the lesson plans. It is important to note that to do a science fair project, students must be able to do the following:

1. Ask a question
2. Write a problem statement
3. Do background research (includes writing a research paper)
4. Choose a solution to the problem and build a working prototype
5. Gather and analyze data; draw conclusions
6. Communicate the findings / results

A **preframe** is a frame of reference given about an experience before the experience has taken place. It is commonly used to set up an activity or action assisting in the anticipation of the result.

Guided Inquiry-Based Investigation is student centered rather than teacher centered. The teacher asks a question of the students. Then the students engage in 4 steps:

1. Driving Question – peeks the students' curiosity and then investigates the answer. The teacher never gives them an answer.
2. Engage
3. Research / Investigate
4. Apply

Example:

1. **Driving Question**: What makes a shadow?
2. **Engage**: Students go on a shadow hunt.
3. **Research / Investigate**
   a. Investigate and conduct studies about properties of light and shadows
   b. Explore computer simulations of laser-light
   c. Create models of light and shadow
4. **Apply**: Students apply the models they created to answer question about light and shadow.

Goals vs. Outcomes - **Goals** are something you are aiming to achieve. For instance, being first across the finish line of a race is a goal. An **outcome** is something that your brain believes you've already achieved.

Why is the wording so important? What we say determines how we feel. Feeling you have accomplished something helps to reduce fear, anxiety - and most important - gives you a positive feeling of pride in your achievement as if it already happened.

Students will be plotting their outcomes on their Timelines.

Anticipatory Set (AS) / Inquiring Question (IQ) is a brief question, activity or event at the beginning of the lesson that effectively engages all students' attention and focuses their thoughts on the learning objective.

What is the purpose of an AS?

- To involve all students, focus everyone's attention, whet appetites.
- To make sure everyone is on the same page, and knows what to do.
- To get the student's attention.
- To refocus everyone's attention to the learning objective after needed interruptions.

What does AS include?

- The anticipatory set must be designed to have direct relevance to the instructional objective, whether that objective is implied or stated in the set.

- **AS** may include a review of significant or related information to establish **continuity** with previous lessons; allusion to **familiar** frames of reference; or demonstrations to ground the lesson in **concrete** operations.

- **AS** provides students with a **label** for the lesson; vocabulary, name, title, overall direction or context for the objective of the lesson.

- **AS** allows the student to know which hook on the hat-rack to reach for when recall of the lesson may be needed.

Methods - Be creative in planning your anticipatory sets!
1. Question(s)
2. Demonstration, especially one with a result the students do not expect
3. Story or anecdote; shock
4. Humor
5. Pertinent news item; role-playing
6. Modeling/visualization

Closure Question(s) is a natural stopping point in the lesson, especially at its end, which points back to the objective and captures its relevance to the unit.

- Closure is **NOT a summary or recapitulation of the lesson!** If a summary is necessary, have the students do it.

- With closure you pass the torch to the learners, who are now the doers and teachers of the objective.

- **Closure is not a teacher activity, but an act of the learner.** Students internalize the lesson in closure and verbalize it to themselves or to each other for increased retention and to facilitate transfer.

- Closure refocuses students' attention on the objective. Answering a question related to the objective, or performing an activity that confirms mastery of the objective gives students the opportunity to recognize what they have learned.

- Closure is like looking back upon a trail so that one knows which way one has come. The lesson may have made perfect sense as long as the teacher was the guide; closure is necessary to ensure that the learners have become future teachers, able to lead other learners along the same trail.

- **Purpose of Closure**
  - To ensure effectiveness of learning (not thoroughness of presentation).

  - To allow students to demonstrate their successful engagement of the lesson.

- Students reapply what they learned; they internalize or verbalize it for retention and transfer (the latter makes for effective closure questions).

- Keeps the big picture in view, either by relating the objective to other fields or topics, or by raising a related question to ponder in anticipation of the next lesson.

- Closure ensures that the objectives are met and applied, as students reapply or label the lesson.

- To make sure they know which train they were on, and where they have gotten off.

Planning effective closure activities takes time! Build it into the lesson plan. Never give up on a lesson and quit before some kind of closure activity.

Lesson Plans

Lesson Plan #1: What is an Engineering Science Fair Project?

Preframe
As a class we are going to be doing an engineering science fair project. The purpose of today's lesson is to learn what an engineering science fair project is and what it entails.

Outcomes
Students will know the definition of an engineering science fair project, how it differs from an experiment or science project, and the purpose of doing an engineering science fair project.

Vocabulary / Spelling Words
engineering science fair project, experiment, science project

Materials Needed
- Internet
- Science textbook
- Teacher's Lesson Plan Sheet – use as an outline for your students. Give each student a copy.
- *7 Secrets of Highly Successful Kids: New Edition* – for Middle School students
- *The Secret* – for High School Students

Step-by-Step Procedure
Anticipatory Set / Inquiring Question
What is an engineering science fair project?

Engage
Ask the class if they know what it means to do an engineering science fair project. Ask for a volunteer to write the responses on a board or newsprint.

Students Investigate / Conduct Studies
Then instruct them how they can find out more about the definition of an *engineering science fair project*. In pairs have the students use the tools they mentioned to research the term.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have students report back to the class with the definition.

Closure Question

What interests you about engineering science fair projects?

Preframe

Doing an engineering science fair project is most likely the longest project you will ever do in middle school or high school. To enjoy the process, I believe it is important to implement success strategies. We are going to read a book over the next few weeks as well as participate in a daily five-minute fun activity.

You are also going to have an opportunity to choose a facet of engineering that interest you and learn about. Over the next #___ of weeks / months you are going to do an engineering science fair project.

> *There will be no tests. You are all starting out with an "A" grade. Actively engage in the class discussions, contribute to your team's efforts, and participate in writing and handing in all the required material and you will keep your "A" grade.*

Homework

Use one of the following books and instruct your students to check it out of the library or purchase the book:

7 Secrets of Highly Successful Kids: New Edition – for Middle School students
The Secret – for High School Students

Tell them when they need to finish the book. The discussion of the book takes place in Lesson #3.

NOTE TO TEACHER: Did you send out the Parent Packet? If not, do so today.

Lesson Plan #2: What is the Difference Between the Engineering Design Process and the Scientific Method?

Outcomes
Students learn about the two different scientific processes, what they are used for, and the distinctions between the two.

Vocabulary / Spelling Words
engineering design process, scientific method, iterative process

Materials Needed
- Internet
- Read in the Student's Guide section – Engineering Design Process vs. Scientific Method

Step-by-Step Procedure
Anticipatory Set / Inquiring Question
What is the difference between using the Engineering Design Process and the Scientific Method when doing a science fair project?

Engage
Ask your students what they know about the engineering design process and the scientific method. From the name of each of the methods, what do you think they are all about…? Let's start with the Engineering Design Process.

Students Investigate / Conduct Studies
In groups of 3 have the students read the Student's Guide or research on the Internet the distinctions between the two methods.

- Optional: YouTube Video showing the differences between the two methods.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation
- Have students report back to the class with the distinctions between the two methods.

- As students report back to the class, ask for a volunteer to make a flow chart on newsprint of the steps of each process.

- After the flow charts are complete, ask the students if all their sources had the same steps or were some different from others.

- Keep the Engineering Design Process chart and hang it on a wall in the classroom so it is visible to the students while they do their project.

- If there is time, you can find a fun video on YouTube.com to show the class about the Engineering Design Process.

Closure Questions

- What are the distinctions that you see between the two methods?
- What is the same?
- If the students had found differences of opinion pertaining to the steps of the Engineering Design Process: What did you think about that?

NOTE TO TEACHER: Explain to the class that the science fair projects that they are going to be doing will follow the engineering design process.

Lesson Plan #3: A Winning Science Fair Strategy

Preframe

Remember we talked about implementing success strategies? That is going to be our focus today. We are going to read a brief story and then watch a fun movie.

Outcome

After completing the following activities students will have a new perspective of what success means.

Vocabulary / Spelling Words

quantum physics, success

Materials Needed

- For Middle School grades– book: *7 Secrets of Highly Successful Kids: New Edition*

- For Jr. High and High School grades – book: *The Secret*

- 3” x 5” note cards – one per student

- Free on YouTube, *What the Bleep Do We Know*, with Marlee Matlin, is 3 hours long. You may want to divide the viewing into 2 or 3 sessions. Features 14 Scientists and has lots of cartoon characters that illustrate how the concepts of quantum physics are visible in our everyday lives. When I viewed it on in the movie theatre, professors from Northwestern brought their students and afterwards held a brief Q&A. It was so much fun. The movie is very easy to understand. Middle school students through college.

- Optional Fun Tools: *Down the Rabbit Hole*, this is a 3-disc special, with an extended Directors Cut (2.5 hours), and a 5-hour Quantum Edition of everything - The Ultimate *What the BLEEP*. *Down the Rabbit Hole* takes the topics introduced in the Original and goes deep, deep, deeper. High School and college students.

- Read in the Student’s Guide section – Winning Science Fair Strategy

Step-by-Step Procedure

Divide this lesson into two or 3 sessions.

- 1st Session: students discuss one of the books listed under **Materials** Needed.
- 2nd Session: whole class watches the movie, *What the Bleep Do We Know*. Or divide watching this movie into 2 to 3 sessions. Well worth the time.

Anticipatory Set / Inquiring Question

Write a couple of inquiry questions on the board. Ask for volunteers to read the questions.

Books Questions

- What does success mean to you? Give an example.
- What do you believe is the most important attribute to have to achieve success?
- Which ones do you believe you have now? How have you lived that success principle in your life?

Movie - *What the Bleep Do We Know*

- What success principles are different in the movie than in the book?
- Which ones are the same?

Engage

Have the students engage in a discussion based on the responses to the above questions.

Students Investigate / Conduct Studies

At the end of each school day, ask the students to record in their Journals success principles that work for them. At various points during the school year have them take out their Journals and share their experiences.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- What is the most valuable concept that you learned from the book and / or the movie that you would like to apply to your life? How would it make a difference?

- What is one action you want to incorporate in your life today?

Give each student a 3” x 5” card on which to write their action. Have them sign it and tape it on a corner of their desk. You do the same.

Closure Question
How important is success to you?

Preframe
At the beginning and end of each day we are going to engage in a success strategy. It is going to be fun and will only take about five minutes. (Choose one of the activities from the bonus eBook, *Building Your Students’ Confidence*.)

NOTE TO TEACHER: Continue to discuss the book during the semester and encourage students to implement the success strategies into their school and daily life.

Lesson Plan #4: How to Create and Keep a Design Notebook

Outcomes

1. Each student keeps a Design Notebook.
2. Each team learns how to make an entry in their journal.
3. Each team expresses the benefits of applying this strategy to other situations in their lives to the class.

Materials Needed

- Read in the Student's Guide section – Design Notebook
- Design Notebook Checklist (print one copy for each student)
- Read in Student's Guide – How to Choose a Design Notebook (put info on web page)

Vocabulary / Spelling Words

design notebook, investigation, engineering laboratory notebook

Step-by-Step Procedure

Anticipatory Set / Inquiring Question:

If you were an engineer what would be the best way to keep track of your project?

Engage

- Divide the class into small groups of 3 to 5.
- Have Design Notebooks displayed in the classroom and have students walk around the room and look at them and take notes.

Students Investigate / Conduct Studies

Have each group gather together. Give time for each group to come to a consensus as to what they believe is important to include in their Design Notebook.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- Have a representative from each group share the group's findings to the class and give reasons as to why they think those choices are important to include in their Design Notebook.

- Give time for each group to create their own list.

- After creating a list, have all the students read the Design Notebook section in the Student's Guide. Then ask them if they added any new items to their list.

Closure Questions

- Go back to the Anticipatory Set and discuss the answers to the question.

- How would using a notebook / journal benefit you in other parts of your life? In other school subjects?

Homework

Each student purchases a Design Notebook.

NOTE TO TEACHER

If the students did not discuss this information, then let them know the following: The Design Notebook is like a journal. Every thought, feeling, idea, learned experience, research, etc. are entered into the Notebook **every day and the entry must be dated**.

Lesson Plan #5: A Unique Way of Using a Timeline

Outcome
Each group becomes aware of the benefits of a Timeline and how to use one.

Materials Needed
- Give a copy of the Timeline worksheet and Directions to each student.
- Design Notebook
- Read in the Student's Guide section - Timeline

Vocabulary / Spelling Words
timeline, goal, outcome

Step-by-Step Procedure
Anticipatory Set / Inquiring Question
- What is the difference between a goal and an outcome?
- What is a timeline?
- What is the purpose of a timeline?

Engage
- Have a classroom discussion about each of the inquiring questions.
- Have one of the students volunteer to be a recorder and write the answers on the board or on a large sheet of newsprint.
- Have the recorder put a line down the middle of the board/paper, one side headed, "Outcomes" and the other headed, "Goals".
- Have the students put the clean, unmarked Timeline in their Design Notebook to be used at a later time.

Closure Questions
- In what other instances in your life do you believe that a Timeline would be useful? Specifically, how would you use it?
- In what other instances would it be beneficial for you to change your language to produce different outcomes?

Lesson Plan #6: What is a Day-Timer?

Outcome
Students learn how to organize their activities and time.

Vocabulary / Spelling Words
daytimer, day planners, personal planners, organize, activities, schedule

Materials Needed
- Internet
- Read in the Student's Guide section – Day-Timer
- Design Notebook
- Timeline
- Lesson Planner
- A Day-Timer (Daytimer.com may send you a sample if you tell them it is for classroom demonstration)
- Shopping List 1 Outcomes Checklist – print one for each student or put on web page.

Step-by-Step Procedure

Anticipatory Set / Inquiring Question:
What method do you use to organize your daily activities and time?

Engage
Have a class discussion and list all the ideas on newsprint.

Show the students your lesson planner and explain how you manage your classroom activities.

Students Investigate / Conduct Studies
Have students work in teams of 2 and do an Internet search, *best way for middle school students to organize their time*.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation
Have the class show their strategies and explain what they did.

Closure Question
What time management strategies would be valuable to you to implement in your life?

Preframe
Tomorrow, towards the end of the day, you are going to make a schedule for your after-school activities, including homework.

NOTE TO TEACHER: If you have time during this lesson, the kids can make their schedule.

Homework
If your students are paying for their materials, it is time for them to look at Shopping List 1 with their parents. Alert the parents on your web page to download the shopping list.

Lesson Plan #7: Identify a Need

Step 1 of the Engineering Design Process
What Kinds of Problems Engineers Solve

Preframe

Before you choose your engineering science fair project, it is important to learn what kinds of problems engineers solve. We are going to divide into teams of 2 today.

Outcomes

1. Students learn what types of problems engineers solve.
2. Students develop a list of facets of engineering.

Materials Needed

- Read in the Student's Guide sections – Engineering Design Process, Overview
- Design Notebook
- Timeline

Vocabulary / Spelling Words

target users, facets of engineering, open-ended design, construction, useful function, cyclical, dynamic process, stagnant process, iterative process

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What are the different facets of engineering?

Engage

In the Student's Guide read the Background and Overview pages related to Engineering.

Students Investigate / Conduct Studies

Choose a partner to work with today. One of the pages in the Student's Guide will lead you to a page that lists the facets of engineering. Make a list of those facets in each of your Design Notebooks and date your entry.

Decide which facet interests you the most. Your partner may have a different interest than you do. Then select a 2nd choice. Star your favorite facet.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Ask the class what facet of engineering interests them the most by reading off the list and having students stand up when the category of his / her interest is read.

How many of you were surprised at what you chose?
How many of you knew right away which one interests you?
Inquire of each student, one at a time, the reason a particular facet of engineering is of interest.

Closure Questions

- What did you learn about yourself?
- Would you apply this process in your life? How? When? (Have a discussion).

Preframe

Tomorrow we are going to divide into permanent teams. The teams will be determined by the facet of engineering that interests you.

Lesson Plan #8: Build Teams Around Facets of Engineering

Step 1 of the Engineering Design Process - Identify a Need

Outcome

1. Form teams of 3 to 5 members according to their interests. These will be permanent teams for the rest of the science fair program.
2. Members of each team to get to know each other.

Materials Needed

- Facets of Engineering – list for teacher
- Design Notebook

Vocabulary / Spelling Words

(not included in this lesson)

Directions to Students

Today we are going to form permanent teams of 3 to 5 people. The team members will consist of people who have the same interest.

Step 1: Take out your Design Notebook and find the facets of engineering list that you made yesterday. You starred the one that interested you the most. Please stand if you chose the facet, Applied Engineering. Tell the students what the facet entails and what kind of research is done. Instruct all the people who are standing to go to a section of the room.

Continue down the list until all the students are in a group according to a facet of engineering. At first it may just be a team of one.

Step 2: Depending upon the age of the students and their abilities, select 3 to 5 students for each team. If there are less than 3 people in a group, negotiate with the kids to join together and find a common facet that they would be willing to work on. Their 2nd choice can act as an alternative.

Step 3: Have each team decide upon a team name. For the duration of the science fair project lessons, students will remain in the team that was just formed.

Step 4: In your Design Notebook write each of your team members name, address, home telephone number, cell phone number (if they have one), and email address so that you can communicate about your project and join together for homework assignments.

Lesson Plan #9: Develop a "Bug" List

Step 1 of the Engineering Design Process - Identify a Need

NOTE TO TEACHER: Unless otherwise noted, students will work in teams for the remainder of the science fair lessons.

Outcome

Develop a "Bug" List

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – Generate Engineering Project Ideas

Vocabulary / Spelling Words

bug list, informal survey

Preframe

Before you can solve a problem, you must identify and define the problem that your team is going to solve. Problems are everywhere. Either someone has a problem with something they are trying to do or they need something to help them to solve a problem.

Take out your Design Notebook because you are going to use it today. In fact, every time we have a science fair lesson, keep your Design Notebook and Timeline with you. Date every entry in the Notebook. Check off the steps as you complete them on the Timeline.

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Read the following to your class, waiting until all students have finished answering each question before moving onto the next:

I am going to ask you 3 questions, one at a time. Don't think about your response. In your Design Notebook, write down your first thought. If you cannot think of anything, that is OK? Here we go…

1. What bugs you in your life?
2. What is needed to make your life easier?
3. What is something that you use but it doesn't work good enough to do the job? This can be a product or computer program.

Engage

Ask for 3 volunteers to write a list on a piece of newsprint at the front of the class. One person will write a Bug List, one person a Needs List, and one person a Product Dissatisfaction List.

Students Investigate / Conduct Studies

Direct each member to share with each other their list. Then, have each person tell the class his/her needs, bugs, and dissatisfaction.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Tell the teams to put a star in front of the "bug" or "need" that interests them the most and determine want piques their interest. Leave time to discuss your choices.

Closure Question

Choose another spokesperson from your team and share what makes you interested in a particular bug, need or dissatisfaction.

Homework

Tonight you are going to do what is called an informal survey. Ask your parents, siblings, neighbors and family members the same 3 questions I asked you.

1. What bugs you?
2. What is a problem that they would like to solve in regards to making their life easier?
3. What is a product that they think needs to be improved?

Write all the responses in your Design Notebook. Bring your list to school tomorrow. We are going to add it to the list and have fun doing a class exercise.

Lesson Plan #10: Choose a Problem or Need to Solve

Step 1 of the Engineering Design Process - Identify a Need

NOTE TO TEACHER: Ask the students to quietly group together in their teams.

Outcome

Each team chooses a problem or need to solve for their engineering design science fair project

Materials Needed

- Design Notebook
- Timeline

Preframe

Join into your teams. Be sure to bring your Design Notebook. Did you date your entries from last night? If not, do it now.

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Let's find out the responses to the 3 questions you asked your family and friends last night.

Engage

Ask 3 students at a time to come write the responses on the newsprint lists from yesterday. Do this until all the students have added their information to the lists.

Students Investigate / Conduct Studies

Now we are going to decide what bug, need and product dissatisfaction belongs in what facet of engineering. Make the decisions as a class and have a student note the facet next to each item.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

As a team, decide which bug, need or product dissatisfaction the team may be interested in solving and the reason you chose it.

Closure Question

Choose a spokesperson from your team and share what particular bug, need or dissatisfaction you are thinking of solving and why you chose that problem.

Lesson Plan #11: Mind Mapping a Problem

Step 1 of the Engineering Design Process - Identify a Need

Not to Teacher: This section of the Lesson Plan may take 2 sessions.

Outcome

Each team uses Mind Mapping to generate ideas for their project.

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – Mind Mapping

Preframe

Join into your teams. Be sure to bring your Design Notebook with you.

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Have you ever done Mind Mapping? Raise your hand if you have. It is a lot of fun and a creative way of generating ideas when doing a project of any kind.

Engage

If you have done Mind Mapping, tell us about your experience.

Let's map a problem or need. Let's choose on from one of the 3 lists that was not chosen by one of the teams. We'll vote to see which one the majority wants to use. Then, as a class, we are going to mind map the problem.

Students Investigate / Conduct Studies

Ask each team to Mind Map their possible problem or need, starting with the key concept in the center and branching out into the details.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Ask each team to choose a spokesperson and explain their Mind Map.

Closure Question

Do you have any questions or concerns about the project your team chose to do? This is the time to speak up.

Preframe

After you mind map your problem or need, based upon what you found, tomorrow you will write a Problem Statement.

Lesson Plan #12: Writing the Problem Statement

Step 1 of the Engineering Design Process - Identify a Need

Outcomes

Each team writes a Problem Statement

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – Write a Problem Statement
- Problem Statement Outcome Checklist (print a copy for each team)

Vocabulary / Spelling Words

problem statement

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is the one problem that you would like to solve?
Who has the problem or need?
Why is it important to solve?

Engage

Take out your Design Notebook and as a team, write an answer to each of the above questions. Write your Problem Statement.

Students Investigate / Conduct Studies

Have the students read the section of the Student's Guide on how to write a Problem Statement. After reading this section give them time to refine their written Problem Statement.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have a spokesperson from each team stand and share their statement. What is the reason it is important for your team to find a solution to the problem that you chose?

Closure Questions

- What did you learn about the importance of writing a Problem Statement?
- How will finding a solution to your problem make a difference in other people's lives? Have a discussion.

Homework

Give a Problem Statement Checklist to each team and allow time for them to fill it out. Tell them to bring the filled-out form home and to ask one of their parents to sign the form. They are to bring the form back to school the next day. You will look it over when you meet with each of the teams.

Lesson Plan #13: What is Background Research and its Purpose?

Step 2 of the Engineering Design Process

Outcome

Students learn about background research and its purpose.

Vocabulary / Spelling Words

background research

Materials Needed

- Timeline
- Design Notebook
- Internet
- Read in the Student's Guide section – Background Research. Read the 1st three pages of this section.

Step-by-Step Procedure

Anticipatory Set / Inquiring Question:

What is background research?

Engage

Have a classroom discussion using the following questions:

- What do you believe is background research?
- What do you believe is the purpose of background research?

Students Investigate / Conduct Studies

In the Student's Guide section read about background research, 1st three pages.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have a discussion about why it is important to do background research and where to find information.

Closure Question

How can doing background research impact the decisions you make in your life?

Lesson Plan #14: What is a Bibliography?

Step 2 of the Engineering Design Process – Background Research

Preframe

You learned in the last science fair lesson that you are going to research various types of references. Part of background research is organizing these references into what is called a bibliography.

Outcome

Students learn about what a bibliography is and the purpose of it.

Vocabulary / Spelling Words

reference materials, bibliography

Materials Needed

- Design Notebook
- Timeline
- Internet
- Read in the Student's Guide section - bibliography
- Dictionary
- Science textbook
- Magazine articles
- Bibliography Checklist (print one or two pages for each team)

Step-by-Step Procedure

Anticipatory Set / Inquiring Question:

What is a bibliography and what is its purpose?

Engage

Has anyone heard the term, bibliography?
(If no one responds, then continue on to the next section.)

Students Investigate / Conduct Studies

Using the resources listed in the Materials Needed section of this lesson plan, ask the students to investigate the word, bibliography, and its purpose.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have each team examine their science textbook and magazines.

- Where do you find a Bibliography?
- What is its purpose?
- What did you notice was listed in the bibliography?

Closure Question

When would you want to look at a bibliography in your everyday life?

NOTE TO TEACHER: Give each team one or two copies of the Bibliography Checklist and ask them to fill out the form now. Remind them to attach the form in their Design Notebook and date the entry.

Lesson Plan #15: Note Cards and How to Use Them

Step 2 of the Scientific Method – Background Research

Preframe

Today you are going to learn how to use note cards to gather information when doing background research. Using note cards is a simple way to organize information and references.

Hold a note card in your hand and show the class what it looks like.

The information you gather will help you to decide how to design your science fair project, how to write your project report and bibliography. All the information on how to do this is in the *Student's Guide*.

Outcome

Students learn how to use note cards when doing background research, writing their science fair report and bibliography.

Materials Needed

- Read in the Student's Guide section – Note cards
- 6" x 4" white and color note cards
- Science textbook
- Science magazines
- Design Notebook
- Timeline

Step-by-Step Procedure

Anticipatory Set / Inquiring Question:

- How to do you use note cards when doing your background research?

- What is the best way to take notes?

Students Investigate / Conduct Studies

Read the section about note cards in the Student's Guide.

Engage

Ask the students if they have any questions or if there was something that they did not understand from what they read.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- Have the students take out their science textbook. Choose a page to read, write one bibliography card and one card with notes.

- Have them read an article that has references at the end of the article. Show them how to trace the studies cited in the article back to the original research source.

Closure Question

How do you think your note cards are going to be helpful to you when doing your science fair project report?

Preframe

Tomorrow we are going to learn more on how to use note cards to keep track of your references and take notes when you do your background research. Ask each team to bring five 6” x 4” white and twenty 6” x 4” color note cards. If you haven’t purchased them already, please do so after school today.

Lesson Plan #16: How-To Make a Background Research Plan

Step 2 of the Scientific Method – Background Research
Gather Background Information on Your Solution

Preframe

There are two parts to making a background research plan: 1). Doing a keyword search: 2). Writing Keyword Questions. We will probably need two science fair sessions to complete this section and some of you may have to finish it as homework.

Outcomes

- To know what scientific research is and is not?

- To learn what the difference is between authoritative sources and non-authoritative sources. To learn what is original research.

  If someone asks, what does authoritative mean, ask them where they think they could find that answer. Then wait for them to look up the definition in a dictionary or on the Internet.

- Students master the art of doing science research on the net, and by using journals, magazines and books.

- To find keywords / keyword phrases for their topic and write them in the **Keyword Worksheet** printable.

- Using the **Question Keyword Worksheet** printable, to write questions and research the answers on the Internet.

- Students learn how to record their research findings and organize their note cards into subtopics.

- Students, from their research, find techniques and equipment others have used when creating a similar solution.

Materials Needed

- School library and librarian – arrange with the school librarian to show the kids where to find reference material and how to search ERIC.
- Public library card
- Internet access
- Read in the Student's Guide sections – Details about Keyword Worksheet and Details about Question Worksheet
- Note cards
- Keyword Worksheet (print one copy for each team)
- Keyword Question Worksheet (print one for each team)
- Keyword and Question Checklist (print one copy for each team)
- Design Notebook
- Timeline

  Keyword search and project research resources
  https://www.wordtracker.com/ , http://www.wikipedia.org
  http://www.encyclopedia.com , magazines

Vocabulary / Spelling Words

original research, magazines, encyclopedia, author, authoritative sources, non-authoritative sources

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is the best way to use resource materials in the library to research information on your project?

Engage

- Engage the students in a conversation; have someone do the recording on the board, writing each of the answers to the above question.

- Have students read the section in their textbook and Student's Guide about background research, how to do a keyword search, how to write keyword questions and about original research.

Students Investigate / Conduct Studies

- Lead a class discussion about why students believe that scientific research is important and the purpose of doing science research before a science fair project.

- Arrange in advance for the class to have the school librarian show them the reference materials and how to use them.

- Students work with their team and fill out the Keyword Worksheet and write the questions for their Keyword Question Worksheet. This may take a couple of days to complete.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

What tips can you give your classmates that would make it easy for them to find information for their project?

Closure Question

Now that you've completed your worksheets, what specific aspect of your project are you going to focus on?

Homework

Each team needs to meet and write the answers to the questions that they wrote for their Keyword Question Worksheet. If they cannot do this at home, or on the internet with Zoom or Google Meet. If none of these options are possible, provide extra school time to complete the assignment. Suggest that they look at an example of a keyword question chart.

Lesson Plan #17: Research – Ask an Expert

Step 2 of the Scientific Method – Background Research

Outcomes

1. Know what determines an "expert".
2. Know the protocol of how to obtain an appointment, give an interview, and write up findings from the interview.
3. Learn the importance of using interviews from experts as a research methodology.
4. Learn how to network within a group to find experts / resources. Experience how a community works together to help one another.

Materials Needed

- Appointment calendar
- A recording device
- Timeline
- Design Notebook
- Transportation
- Skype or Face Time for long distance interviews
- Video tape of interview when possible
- Letter of Inquiry handout (print one copy for each team)
- Read in the Student's Guide section networking (and/or on the Internet)
- Read in the Student's Guide section - How to Interview Experts

Vocabulary / Spelling Words

expert, interview, researcher, expertise

Step by Step Procedure

Anticipatory Set / Inquiring Question

The best way to gain an interview with an expert: If you were a very busy person, what would you want people to do to respect your time and yet provide you with an opportunity to give value to another person or persons?

Engage

- Brainstorm various means of doing an interview. (in person, telephone, etc.)

- Have a classroom discussion on the best way to obtain, conduct and record an interview.

- Instruct each team to choose a spokesperson to stand up in class and tell what their specific facet of engineering is about, read their Problem Statement, and tell the kind of expert they want to interview. Then have them ask the class, “Who do they know, or who do your parents know, who is an expert in that field?” Have all the students take notes on what their classmates need.

- Brainstorm questions that would be best to ask an expert.
  Where is the best place for you to record your questions? (Hopefully by now they will say their Design Notebook!)

Students Investigate / Conduct Studies

- **10-minute interview**: Have each team interview one person from another team. They can ask questions to find out more about their classmate: favorite sports, hobbies, food, subject in school.

- Brainstorm where they can find experts in their communities.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Application of this lesson will take place when the students interview their science expert and report back to the class about what they learned.

Closure Questions

- What did you find out today that would make you an expert interviewer?
- Where else can you apply this in your life?

Homework

Write a letter of inquiry to the expert you want to interview. Bring it to class tomorrow.

Bring your notes from the interview to class. If you recorded your interview, make sure you have the interviewee’s permission. You can use the recording to take notes and write what the expert said. This assignment will probably take a few days to a week to complete.

- Who do you know, who may you know, that is an expert that one of your classmates could interview? Ask your students to brainstorm people that they could call when they get home.

- Ask students to talk with their parents. Once the parents have the expert's permission to give his/her contact information to members of your class, have them bring it to school the next day and give the referrals to their friends.

Lesson Plan #18: Brainstorm Ideas & Develop Possible Solutions

Step 3 of the Engineering Design Process

Outcomes

1. To propose an idea for solving a problem and explain why it will work.
2. For students to experience various ways to develop solutions to a problem.

Materials Needed

- Read in the Student's Guide section – Brainstorm Ideas & Develop Possible Solutions
- Design Notebook
- Timeline

Vocabulary / Spelling Words

brainstorming, ideation, doodling, analogies

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What are the various ways of developing solutions to a problem?

Engage

Read the rules on how to brainstorm in the Student's Guide: Brainstorm or Ideation. Then have the class do a brainstorming session on what they believe are various ways of developing solutions to a problem. While they are brainstorming the solutions, have someone write their ideas on newsprint at the front of the room.

Students Investigate / Conduct Studies

Tell students to read about various ideas in the Student's Guide.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- Ask all members of each team to doodle or sketch possible solutions to their problem.

- Ask each team to either brainstorm or make analogies as a way to develop solutions to their problem.

Closure Questions
What did you learn from doing the exercise? What was helpful? What did not produce results? Ask teams to show their doodles and sketches.

Homework

The homework will probably take 2 days to a week to complete. Remember to document and date everything you do in your Design Notebook.

1. When you go home tonight, implement the strategy, Sleep On It! You can reread about this strategy in the Student's Guide.

2. If you are thinking of improving upon a product or building a new one, then use the strategy, Examine Existing Products, which is also explained in the Student's Guide.

Bring the homework to school on ___(day/date)______. Also bring the products you examined.

Lesson Plan #19: Specify Your Design Requirements

Step 3 of the Engineering Design Process – Brainstorm Ideas & Develop Possible Solutions

Outcomes

1. Share the results of their homework
2. Learn about the 4 different types of products you can design
3. Learn about design criteria and constraints
4. Learn about design requirements

Materials Needed

- Read in the Student's Guide section – Specify Your Design Requirements
- Design Notebook
- Timeline

Vocabulary / Spelling Words

design requirements, design criteria, characteristics

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is important to know when determining the design requirements for your solution?

Engage

What do you believe is important to know when designing a solution to your problem? Have the students sit in a circle or around a "U" shaped conference table and engage in a conversation. While the conversation is going on, as the teacher, write their ideas on large newsprint paper.

Students Investigate / Conduct Studies

Read the section, Specify Your Design Requirements, in the Student's Guide.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- Ask each team to decide what type of product they are going to design. There are 4 options listed in the Student's Guide. They will need to choose an option and explain their choice.

- Instruct each team to list 3 to 5 design criteria and whatever constraints they believe are present.

  This will probably take a few days to a week because they are going to have to research existing products that are similar to what they want to design. This section can be done as homework or you can give them classroom and school library time.

Closure Question

If you have any questions about writing your design criteria and constraints, now is the time to ask. This is a very, very important step in this process. It must be very specific. It involves all key information for solving your problem or need. To accomplish this task, you will be using all the information you gathered from your research. Any questions?

Some questions may come up while you are writing your lists. Don’t hesitate to ask.

Lesson Plan #20: Write a Design Brief

Step 3 of the Engineering Design Process – Brainstorm Ideas & Develop Possible Solutions

Preframe

Today you are going to write a Design Brief.

Outcomes

1. Know what a Design Brief is and how to write one.
2. Each team writes a Design Brief.

Materials Needed

- Read in the Student's Guide section – Write Your Design Brief and Proposal Form
- Proposal Form Worksheet (2 copies per student – 1 for each student, 1 for each parent, 1 copy for each team to give to their teacher)
- Possible Solutions Outcomes Checklist (print one copy for each team)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

design brief, target user

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is a Design Brief and what must to be included in one?

Engage

Have students read the section about a Design Brief in the Student's Guide.

Students Investigate / Conduct Studies

Have each team write a Design Brief for their problem.

Apply / Students Explain Reasons behind answer to question – based upon their investigation

Taking turns, ask each team to have one member read their Design Brief and explain who their target user is going to be.

Closure Question

Why do you think it is important to write a Design Brief?

Homework

Each student brings home the Proposal Form, has a parent sign it, and bring it back to school the next day.

NOTE TO TEACHER: Meet with each team. The students must bring their signed Proposal Form, Possible Solutions Outcome Checklist, Design Notebook and Timeline.

Make sure that the Design Brief includes the following:

1. Description of target user – Read Research Target Users
2. Definition of the problem they want to solve.
3. Description of existing products and why they feel theirs will solve the problem better
4. The requirements of the design (criteria and constraints)

Keep in mind the parental support of each team, safety guidelines, and practicality. Check Intel's Safety Guidelines and your school's rules. Do not move on to the next lesson plan until you have approved all Design Briefs.

I suggested you post a letter on the website or send a letter home to the parents about the science fair. Now is the time to send another note home with each child reminding the parents of the science fair meeting.

Meet with the Parents: Have the Design Notebooks, Timelines, Checklists, Design Briefs and Proposal Forms on each team's desk. The parents will be impressed with what their children are doing and what life lessons they are learning from this experience. Ask for their help in purchasing materials that will be needed.

Lesson Plan #21: Design Your Solution

Step 4 of the Engineering Design Process - Draw Your Final Design

NOTE TO TEACHER: This lesson will take 2 to 3 sessions

Outcomes

1. Each team makes final design drawings of their solution.
2. Students know how to measure the change the invention will make.
3. Students create a chart showing the attributes of the solution.

Materials Needed

- Read in the Student's Guide sections – Design Your Solution(s), Choose the Best Solution
- Materials needed to make the drawings
- Design Matrix – Instructions, Template I, Template 2 (print 1 copy for each team)
- Design Notebook
- Timeline
- https://www.youtube.com/watch?v=1Hm5Zyjmjac

Vocabulary / Spelling Words

Sketches, drafting, crude prototype, storyboard

Step-by Step-Procedure

Anticipatory Set / Inquiring Question

Today you are going to make a drawing of your design. You are also going to make a chart showing the attributes of your solution.

Engage

- Read the section, Design Your Solution – Draw Your Final Design, in your Student's Guide.

- First make a freehand drawing, then a Technical Drawing if you have the CAD software, and a Pictorial drawing. Each successive drawing will refine and improve your design.

- What criteria do you need to consider when making your drawing?

- Draw a Storyboard describing the use of your product.

- Use the directions and Matrix Templates to evaluate your design.

NOTE TO TEACHER: The Design Criteria is listed in the Student's Guide here….

Students Investigate / Conduct Studies

Make your drawings and your prototype or initial model now. Revisit the needs, constraints and other factors you previously listed in your Design Notebook. Make sure you can measure the change your invention will make.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have each team show their drawings and prototype or model to the class. With the aid of the chart that they made, explain why this is the best solution based upon the criteria listed in the Student's Guide. Then inform each team to use the Design Matrix to evaluate their solution.

Closure Questions

How was making the drawings, prototype, chart and Design Matrix helpful to you? Which final design did you choose?

NOTES TO THE TEACHER

This section is usually addressed when the students fill out the Proposal Form, but if this is the first time your students are doing engineering design projects, it would be important to meet with each team and address the issue of safety. Also…

- Are the student's solutions measurable?
- Are the materials and equipment that they will need available?
- Will they have enough time to complete their project?

If students are doing their project outside of school, address the following:

- Where will they build the solution?
- What safety gear will be needed?
- Do they have the gear or do they need to purchase it? Can the school provide the gear?
- Specifically, who will be supervising?

- Is special equipment needed that a hospital lab or university may own? A hospital or university may have an expert who is willing to mentor and supervise as long as the team builds the solution at their facility.

NOTE TO TEACHER: If you have any question regarding safety or supervision, have the team redesign the solution.

Lesson Plan #22: Write a Step-by-Step Procedure

Step 4 of the Engineering Design Process – Design a Solution

Outcome

Students learn how to write a step-by-step procedure for building a working prototype.

Materials Needed

- Read in the Student's Guide section – Write a Step-by-Step Procedure
- Preliminary Design Outcomes Checklist (print one copy for each team)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

step-by-step procedure

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What steps do you need to take to build your prototype?

Engage

As a team, read about how to write a step-by-step procedure. Then write one for building your prototype or model.

Students Investigate / Conduct Studies

Ask one team at a time to read their procedure.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Ask the class if they have any suggestions to improve the step-by-step procedure.

Closure Question

What specific details must be included to improve your written step-by-step procedure?

Lesson Plan #23: Materials List

Step 4 of the Engineering Design Process – Design Your Solution(s)

NOTE TO TEACHER: Read about the Materials & Supply List in the Student's Guide because the school or students may have some of the recommended supplies.

Outcomes

1. Students learn how to write a Materials List.
2. Students have a materials and supply shopping list to build their prototype and for their display board.

Materials Needed

- Read in the Student's Guide section – Materials List
- Materials List Checklist (print one copy for each team)
- Students use the science fair supplies that the school provides plus what they purchase. Shopping List 2 (for students and teachers)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

materials list

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What needs to be included in the Materials List for building your prototype, writing the Project Report, and making your display board?

Engage

- Read how to make a Materials List in the Student's Guide.
- Instruct each team to write, in detail, all the materials they will need to do make their prototype or model.
- Give the kids time to make a shopping list of what they will need. See what the school can provide and ask the parents for the rest.

Students Investigate / Conduct Studies

(not included in this lesson plan)

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have the students add their list of supplies to Shopping List 2. Delete whatever the school will supply.

Closure Question

What did you learn today that you did not know before we began this lesson?

Homework

- Tell the kids what day they will be building their prototype in the classroom (or at home).
- Take home your shopping list and make plans with your parents to purchase the materials you will need in order to build your prototype.
- If the students need to purchase a display board, header, title tag, etc., let them know what to buy.

NOTE TO TEACHER: Put an announcement on the web page so that the parents know that they need to go shopping and when the supplies are to be brought to school.

Meet with each team and go over the procedure. Make sure it is safe and detailed enough so that the kids can build their prototype.

If your students want to enter a Big Fair, now is the time for them to fill out the forms and submit the necessary information.

Lesson Plan #24: Build a Working Prototype - Solution

Step 5 of the Engineering Design Process

NOTE TO TEACHER: This lesson plan may take up to a week to complete. Some of the work can be done at school and then the working prototype can be done at home, unless you prefer for the students to complete this section in the classroom.

Preframe

Remember we read about the Engineering Design Process? Let's look at the section about building a prototype. What do you notice about the process? (It is an **iterative process**.)

Outcome

Each team builds a working prototype.

Materials Needed

- Read in the Student's Guide section – Build a Working Prototype
- Design Notebook
- Timeline

Vocabulary / Spelling Words

working prototype

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Today you are going to build your working prototype.

Engage

From what you read in the Student's Guide and the work you have done, what is important to know and do when building your working prototype?

NOTE TO TEACHER: Remind the students to note everything they do in their Design Notebook and to date their entry. If they change the step-by-step procedure in any way, it must be written in the Notebook too.

Students Investigate / Conduct Studies

(not included in this lesson plan)

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

(not included in this lesson plan)

Closure Questions

- Does your working prototype need to be refined?
- Does the prototype/model do what you designed it to do?
- Do you need to make some adjustments?

Lesson Plan #25: Test Your Prototype/Model

Step 6 – Test It

Outcome

1. Write a test plan.
2. Write a questionnaire for users to answer before, during and after the testing.
3. Test the prototype on real users.

Materials Needed

- Design Notebook
- Timeline
- Read the section called, Test It, in the Student's Guide.

Vocabulary / Spelling Words

working prototype

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Today you are going write a test plan and develop a questionnaire for users to answer before, during and after the testing of your working prototype.

Engage

What do you need to include in the test plan?

Students Investigate / Conduct Studies

Refer to your background research to find out what kind of test plans others did with a similar prototype.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Write your test plan. Remember to collect data and write it in your Design Notebook.

NOTE TO TEACHER: Follow the same Step-by-Step Procedure question and tasks for developing a user's questionnaire.

Closure Questions

1. Did you need to change your test plan to test your prototype?
2. If yes to the 1st question, did you go back to the users and retest the new working model?
3. How many times did you have to work out the glitches and retest?

Lesson Plan #26: Errors in Measurement

Step 6 of the Scientific Method – Test It
For High School Students

Outcome

Students learn to recognize problems, called errors of measurement, that may develop when designing and making a prototype.

Materials Needed

- Read in the Student's Guide section – Errors in Measurement
- Design Notebook
- Timeline
- Worksheets for errors in measurement
  Here is a site that has Errors in Measurement Worksheets. You do have to pay for them, but it is not expensive for a year's subscription.

Vocabulary / Spelling Words

errors of measurement, imperfections, systematic error, random error

Step-by Step-Procedure

Anticipatory Set / Inquiring Question

What are errors in measurement and why are they important to recognize?

Engage

Have students read about the concepts related to errors in measurement: imperfections, systematic errors and random errors.

Students Investigate / Conduct Studies

Hand out Errors in Measurement worksheets. Have them investigate on the net information about errors in measurement. Tell them to take notes.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have the class discuss the importance of recognizing errors of measurement.

Closure Question
Discuss how students can use the information they gathered plus what they learned from the discussion. How would they apply this information to your science fair project?

Homework
Have students review their design and identify possible errors that it has or could develop.

Preframe
Tomorrow is a very exciting day. You will report back to the class to share your testing plan to see if there may be some errors in measurement. Then we will discuss what errors seem to be the most common amongst each of your designs.

Lesson Plan #27: Data & Conclusions

Step 6 of the Engineering Design Process – Test It

Preframe

Unexpected or failed prototype results do not make for a failed science fair project. You just ran out of time to perfect your solution.

How many times did Thomas Edison fail at finding a means to sustain the light of a light bulb? No one knows. But Edison did not believe in failures. He believed that the more "no's" scientists get, the closer they are to a YES!

Outcome

Students know how to collect and organize data.

Materials Needed

- Read in the Student's Guide section – Data
- Design Notebook
- Free graph & table creator or Graph Paper – if going to use graph paper, students are going to need colored pencils and a ruler
- Timeline
- Prototype Testing Outcomes Checklist

Vocabulary / Spelling Words

data	record data	interpret data	tables
columns	headings	intersecting	bar graph
rows	similar	pie graph	line graph (X-Y)
graph	approximate	consistent data	equation
pie graph	scatter plot	legend (in a table)	pictorial presentation
data points	absolute numbers	time -series plot	

Step-by Step-Procedure

Anticipatory Set / Inquiring Question

What are the different types of data and the best way to pictorially express them?

Engage

Have students read about data graphs and tables here…

Students Investigate / Conduct Studies

Have each team determine the best type of expression for their data.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Each team creates a table or graph to display their data.

Closure Questions

- By organizing your data into a table or graph what more did you learn about the results of your testing?
- What became clearer about your findings?
- What became more confusing?

Lesson Plan #28: Draw Conclusions

Step 6 of the Engineering Design Process – Test It

Outcome

Each team draws conclusions from the data that they collected.

Materials Needed

- Read in the Student's Guide section – Drawing Conclusions
- Data Analysis Checklists (print one for each team)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

draw conclusions, analyze, investigation, explanation, compare data

Step-by Step-Procedure

Anticipatory Set / Inquiring Question

What conclusions did you draw from your data?

Engage

Discuss the Inquiring Question.

Students Investigate / Conduct Studies

Online, read other people's conclusions.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have students analyze the data they collected; write up their findings in their Design Notebook and date their entry.

Minimum requirements:

- One paragraph that describes the data that was collected.

- One paragraph that explains if the data shows that the solution is working the way you want it to. Why didn't it work well? How could it be improved? Did the design meet the design criteria?

Closure Question

What value did you find in writing your conclusions?

Lesson Plan # 29: Refine, Redesign and Retest as Needed

Step 7 of the Engineering Design Process

Lesson plans not included in this section, except to read about this step in the Student's Guide.

Lesson Plan #30: How to Write a Project Report

Step 8 of the Engineering Design Process – Communicate Results

Students in Middle School are best served by the whole class writing the report together with the guidance of their teacher.

Preframe

The report pulls together all the information that you created, including the research paper. By doing a Project Report you gain and demonstrate understanding of your project.

Outcome

Students learn what is included in a science fair project report.

Materials Needed

- Design Notebook
- Timeline
- Computer and printer
- Dictionary
- Read in the Student's Guide sections – How to Write a Project Report and 1st draft
- Project Report Outcomes Checklist

Vocabulary / Spelling Words

science fair project report, 1st draft

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What sections do you believe need to be included in your Project Report?

Engage

Have the class divide into their teams, look over their Design Notebook and make a list of what they believe needs to be included in their report.

Students Investigate / Conduct Studies

Have the students refer to their Student's Guide to see what they could add to make their report more complete.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Have each team report back to the class and tell whether or not they agree or disagree with each other's findings.

Closure Question

Discuss what the value is in doing a Project Report.

Homework: Each team writes the first draft of their science fair Project Report.

Give them 1 to 2 weeks to complete this assignment. It will take Jr. High and High School students at least a week or more because they have to include more details.

Have students mark the date in their date calendar and Design Notebook because they must have their first draft brought to class on time.

Make this fun. Ask a volunteer to hold up a sign at the end of each day that reminds the kids what they need to do that night.

It would be helpful if the whole class decides what section of their report is due. Then ask them to set the day the first draft is due and plot it on their timeline.

Lesson Plan #31: Writing the 2^{nd} Draft

Step 8 of the Engineering Design Process – Communicate Results

On the day the 1^{st} draft is due have the teams exchange papers and read each other's Project Report. Have them make helpful suggestions in the margins. Then return the papers to their owners.

Homework

Tell the students to take home their first draft and revise it, taking into consideration the feedback they received. "This becomes your 2^{nd} draft. Bring it to class tomorrow."

Lesson Plan #32: Writing the Final Draft of the Project Report

Step 8 of the Engineering Design Process – Communicate Results

Outcome

Students revise their reports and create a final Project Report.

Materials Needed

- Read in the Student's Guide section – Final Copy
- Final Project Report Checklist (print and make a copy for each student)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

2nd draft	title page	table of contents	summary
conclusion	references	acknowledgements	introduction
discussion	project title	final draft	

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is the best way to be helpful when evaluating another person's work?

Engage

- Ask the anticipatory question of the whole class.

- Have the teams exchange papers again and if they have any suggestions to write them in the margin.

Students Investigate / Conduct Studies

(not included in this section)

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

(not included in this section)

Closure Question

What did you learn from this experience?

<u>Homework</u>
Take home your 2nd draft with the suggestions. Ask an adult who is an excellent writer to make suggestions in the margin using a different colored ink pen than your fellow classmates did.

NOTE TO TEACHER: Give a deadline for when the final report is due.

Lesson Plan #33: How-To Write an Engineering Science Fair Abstract

Step 8 of the Engineering Design Process – Communicate Results

NOTE TO TEACHER: Some Middle School grade students will need the guidance of a parent / teacher when writing their abstract.

Outcome

Students learn what sections are required in an Abstract and how to write one.

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – How to Write an Abstract
- Abstract Template (print one copy for each team)
- Abstract Check list Worksheet (print one copy for each team)

Vocabulary / Spelling Words

abstract	introductory	paragraph	purpose of the project	procedures
key points	data	conclusion	problem statement	results

Step-by-Step Procedure

Follow the same procedure as you did when you learned how to write a Project Report.

Example of Abstracts for Evaluation by the Students

Find Abstracts on the Internet and evaluate them.

Homework

Teams write their Abstract and then print it on clean white paper.

Lesson Plan #34: How-To Make an Extraordinary Display Board

Step 8 of the Engineering Design Process – Communicate Results

Preframe

The display board is the first impression that the Judges sees when evaluating your science fair project. It is a display that tells the story of your project, showcases your efforts, and is required at an expo or science fair.

It is best to keep the board design simple, very neat and well organized unless your school has different expectations.

Putting together the display board may take 2 – 3 days.

NOTE TO TEACHER: The Student's Guide has a very detailed explanation on how to design and make a display board. If you can, print a copy of this section for each of the teams, otherwise give them time to read it and take notes.

If at all possible, have the students make the boards during school hours. It will be less expensive and time consuming for your students.

Outcomes

1. To have fun!
2. To create a display board that is organized like a newspaper.

Materials Needed

- Read in the Student's Guide section – How to Make a Display Board
- Display Board Checklist (print one copy for each team)
- Opaque projector (optional)
- Printed Report and / or Abstract
- Examples of display boards in the classroom (when available)
- Design Notebook
- Timeline

Vocabulary / Spelling Words

display board	materials	color scheme	title of board
subtitle	title headings	drawings	photographs
generated	models	equipment	computer

Step-by-Step Procedure

Anticipatory Set / Inquiring Questions

What would cause you to look at a display board from across the room?

If the display board is a pictorial summation of all your work, what do you believe it needs to include?

Engage

Walk around the room and look at all the display boards. Then stand in front of your favorite. Ask each student, in one sentence, to justify his / her selection.

Students Investigate / Conduct Studies

Read the section in the Student's Guide on how to create a display board.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Hand out the Display Board Checklist Worksheet printable and have each team make a display board.

Before anything is permanently put on the display board, have students gather around each team's board and give positive comments and suggestions.

Closure Question

What did you learn from putting together your display board?

<u>Homework</u>

If the students purchase their materials, put the list of items they will need to purchase on the web page and where to buy them. You are welcome to copy and print the pages from the Student's Guide.

Lesson Plan #35: How do Science Fair Judges Think?

Step 8 of the Engineering Design Process – Communicate Results

Outcomes

Students are prepared for science fair judges' expectations.

Students know how to impress the judges by being able to answer their questions with ease without using note cards.

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – How Judges Think
- ISEF Criteria Checklist

Vocabulary / Spelling Words

judge, criteria, evaluate, technical skill

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

If you were a judge at a science fair, what would you want the students to know?

Engage & Students Investigate / Conduct Studies

If a science fair is in your area, ask the students to attend it. Suggest that they talk with the judges. If they can be present when the judging takes place then they could listen in on what will be expected of them.

Have them tell you what behavior they believe would be expected as a guest at someone else's science fair. Send a note, email and/or place a notice on your web page asking the parents to take their child to a science fair.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

- Hold a mock classroom science fair. Have students take turns being science fair judges and science fair participants. This can coincide with your students' science fair projects presentations. (see Lesson Plans #36 and #37)

- Have students give their judge's score sheets with their comments and scores to each team of presenters.

Closure Questions

- After the fair is over, ask the students to share what they learned by being a Judge.

- What did they learn by being a demonstrator?

- What would they do differently next time?

Lesson Plan #36: What are Crutch Words?

Step 8 of the Engineering Design Process – Communicate Results
In preparation for doing a classroom presentation and talking to the judges

Preframe

During the next science fair lesson, you are going to learn how to give a verbal presentation to the class about your science fair project. The same principles you will learn on how to give a speech are the same as when you present your project to the judges at the science fair.

Today we are going to learn about crutch words.

Outcomes

1. To become aware of crutch words used when speaking.
2. To start eliminating crutch words.

Materials Needed

- Read in the Student's Guide section – Crutch Words
- Timeline
- Design Notebook

Vocabulary / Spelling Words

crutch words

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

What is a crutch word?

Students Investigate / Conduct Studies

Ask the students to read the section about crutch words in the Student's Science Guide. They can also investigate the keyword phrase on the internet.

Apply / Students Explain Reasons behind answer to question – based upon their investigation

Direct the class to divide into their teams. "Everyone uses crutch words, so let's just have fun with this exercise."

Each member of a team gives a spontaneous five-minute talk about their favorite subject. The other members of the team take note of any crutch words that the speaker may have said. Then have the team members give feedback to the speaker.

Engage

Ask students to raise their hands if they used any crutch words. Then ask those who did not use crutch words to raise their hands. Discuss with them what was easy or difficult about avoiding crutch words.

Closure Question

What is a good reason to eliminate crutch words from your speaking and writing?

Lesson Plan #37: How to do a Presentation before Classmates or at the Science Fair

Step 8 of the Engineering Design Process – Communicate Results

NOTE TO TEACHERS: Doing a classroom presentation is an optional activity, but well worth the time and effort because learning how to give a presentation is a life-time skill that builds confidence, enthusiasm and pride. After all, your students just completed a HUGE endeavor. They deserve to showcase their efforts.

Outcomes

1. For each student to feel comfortable, have self-confidence, and do a presentation with panache!
2. To be aware of the components of a verbal presentation.

Materials Needed

- Read in the Student's Guide section – How to do a Classroom Presentation
- Note cards
- Design Notebook
- Timeline

Vocabulary / Spelling Words

public speaking	verbal presentation	gestures	eye contact
conclude	rehearse	memorize	

Step-by-Step Procedure

Anticipatory Set / Inquiring Question

Let's say that you are listening to a presentation about a science fair project. What would you want to hear? How would you like it to be presented?

Engage

Spontaneously, ask each student to come to the front of the room, state one interesting fact about their science fair project in only one sentence. No judgment, no comments. Make it fun!

Students Investigate / Conduct Studies

- Read the section in the Student's Guide on how to do a presentation.

- Tell students to find videos about science fair projects on YouTube and list ideas of what kept them interested in the presentation.

Apply / Students Explain Reasons behind their answer to the question based upon their investigation

Students make an outline on their note cards of the highlights of what they would like to present for their classroom verbal presentation.

Closure Question

What did you learn and how are you going to apply it to your presentation?

Have each team sign up on a schedule to give a science fair presentation.

Homework

Practice presentation at home.

Lesson Plan #38: The Day of the School Science Fair

Step 8 of the Engineering Design Process – Communicate Results

Outcomes

1. To assure that your students feel comfortable at the science fair.
2. To make sure that they know how to dress.
3. To assure that students know the behavior code.

Materials Needed

- Design Notebook
- Timeline
- Read in the Student's Guide section – Day of the Science Fair

Procedure

- Hang loose today with the kids. Have an informal get-together. Tell the class that we are all going to relax and have a comfortable, loose discussion.
- Have the class read the Student's Guide on what to do at the Science Fair.

Engage

Have a discussion on what are the best practices when being a presenter at the science fair.

NOTES TO TEACHER

- Lead them through a relaxing process.

- This is the time to tell your students how proud you are of them, of all their effects. Let them know what an extraordinary accomplishment they achieved. Tell them that they are all winners as far as you are concerned.

Postscript

Let me know about your experience by leaving a testimonial. We really are interested. If there is anything that you believe we need to do to improve this guide, let us know that too.

You are welcome to email comments, suggestions or ideas to Mdbinder1942@gmail.com

Most important, have your kids participate in Super Science Fair Project's free, international online Science Fair Enthusiast's contest. All students who participate in the Olympiad receive an award certificate and a T-Shirt. Prizes are awarded.

Thank you for using this book.

Cheers!
Madeline

Printables for Teachers

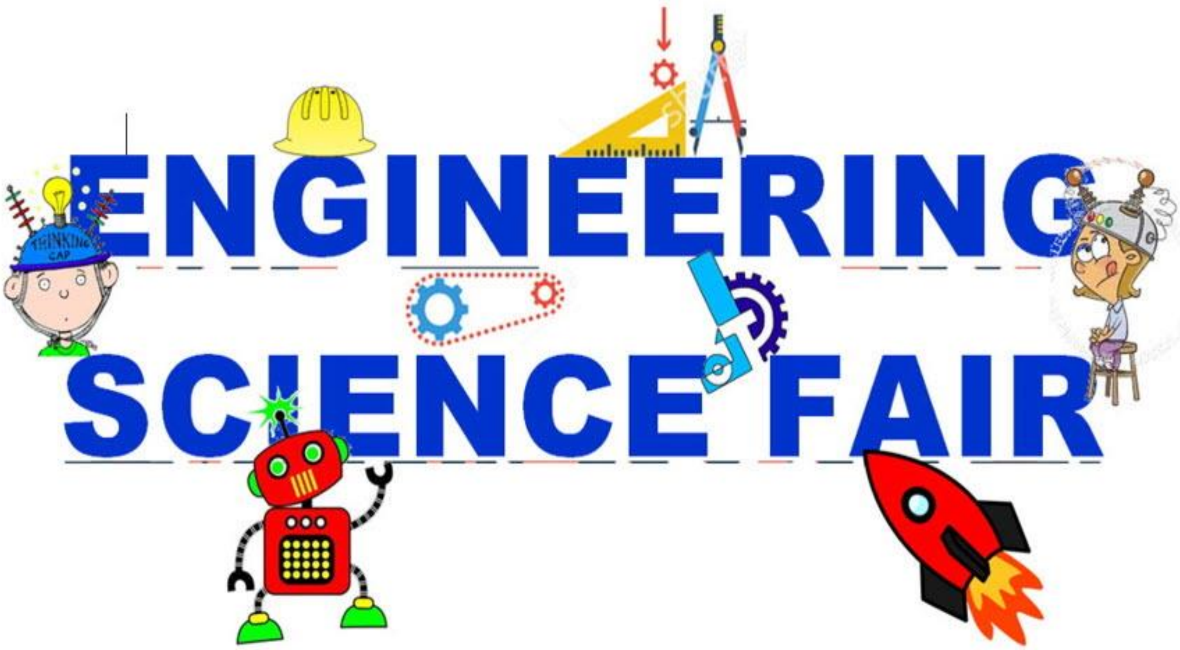
Sensory Based Words

VISUAL		AUDITORY		KINESTHETIC	
See	Pretty	Music	Resounding	Fumble	Survey
Dark	Foggy	Loud	Discuss	Merge	Reveal
View	Survey	Aloud	Purr	Lift	Spotless
Portray	Reveal	Verbalize	Chant	Throw	Image
Neat	Spotless	Say	Listen	Hot	Sight
Vision	Pattern	Yell	Voice	Tension	Glare
Dull	Show	Sing	Sound	Reach	Shine
Appear	Watch	Babble	Shout	Jarring	Draw
Cloudy	Reflect	Argue	Whisper	Cram	Clear
Light	Observe	Clatter	Boom	Pack	Dim
Look	Visible	Shrill	Snore	Sturdy	Sketch
Sketch	Focus	Clang	Quiet	Rough	Watch
Bright	Oversight	Utter	Describe	Steady	Feel
Scan	Picture	Tell	Hiss	Soft	Compute
Hazy	Hear	Praise	Call	Balance	Cool
Ugly	Talk	Ring	Noise	Push	Support
Hide	Rasp	Silent	Scream	Trudge	Tiff
Brilliant	Sing	Grumble	Speak	Massage	Handle
Strain	Whine	Squawk	Squeal	Attach	Fall
Blind	Tone	Debate	Cool	Grasp	Electric
Image	Glare		Sting	Shape	Unite
Clear	Shine			Pinch	Take
Draw	Sketch			Tension	Sharp
Watch	Point			Tough	Extend
Sight	Chime			Warm	Rough
	Quiet			Shape	Grab
				Press	Push
				Punch	Connect
				Ugly	Link
				Hide	Tackle
				Brilliant	Smooth
				Strain	Hard
				Blind	Cold
				Pretty	
				Foggy	

Lesson Plan Schedule - This is a flexible schedule. Check our classroom website for changes.

<!--- insert the URL of your website address and delete these instructions -->

Science Fair Projects – What is being taught and if there is homework on that day.		
Date	**Subject of Lesson Plan**	**Homework**
	What is a science fair project?	X
	Difference between Engineering Design Process & Scientific Method	
	Winning strategies for success	X
	How to create and keep a Design Notebook	X
	What is a Timeline? We fill one out in class.	
	What is a Day-Timer	X
	Build teams around facets of engineering	
	Develop a "Bug List"	X
	Choose a problem or need to solve	
	Mind Mapping a problem	
	Writing a problem statement	
	How to do background research and its purpose	
	What is a bibliography?	
	Note cards and how to use them	
	How to make a background research plan	X
	How to interview an expert for background research	X
	Brainstorm ideas and develop possible solutions	X
	Specify design requirements	
	Write a Design Brief	X
	Design a solution	
	Write a step-by-step procedure	
	Learn about and write a materials list	X
	Build a working prototype - solution	
	Test prototype / model	
	For high school students: errors of measurement.	X
	How to interpret and record data	
	How to draw conclusions	
	Refine, redesign and retest prototype as needed	X
	How to write a Project Report	X
	How to write a first draft of Project Report	X
	Writing 2nd draft of Project Report	X
	Writing final draft of Project Report	X
	How to write an abstract.	X
	How to construct a display board	X
	How science fair judges think	
	What are crutch words	
	How to do a presentation before the class or at science fair	X
	Students give their presentation to their class over several days	
	What you need to be prepared when you go to the Science Fair	
	The Day of the Science Fair	



When:

Time:

Where:

Cartoon to put on website.

Instructional Model Chart – Teacher's Role

Steps of Instructional Model	Inquiry-Based Learning (Student Centered)	Traditional Model (Teacher Centered)
Engage	◦ Creates interest ◦ Generates curiosity ◦ Raises questions ◦ Elicits responses that uncover what students know or think about the concept/topic	◦ Explains concepts ◦ Provides definition and answers ◦ States conclusions ◦ Provides closure ◦ Lectures
Explore	◦ Encourages students to work together without direct instruction from the teacher ◦ Observes and listens to students as they interact ◦ Asks probing questions to redirect student's investigations when necessary ◦ Provides time for students to puzzle through the problems ◦ Acts as a consultant for students	◦ Provides answers ◦ Tells or explains how to work through the problem ◦ Provides closure ◦ Tells students that they are wrong or right ◦ Gives information or facts that solve the problem ◦ Leads students step-by-step to a solution
Explain	◦ Encourages students to explain concepts and definitions in their own words ◦ Asks for justification (evidence) and clarification from students ◦ Formally provides definitions, explanations and new labels ◦ Uses students' previous experiences as basis for explaining concepts	◦ Accepts explanations that have no justification ◦ Neglects to solicit students' explanations ◦ Introduces unrelated concepts or skills
Elaborate	◦ Expects students to use formal labels, definitions and explanations provided or given to them ◦ Encourages students to apply or extend concepts and skills in new situations ◦ Reminds students of alternate explanations ◦ Refers students to existing data and evidence and asks questions: What do you already know? Why do you think…?	◦ Provides definitive answers ◦ Tells students that they are wrong or right ◦ Lectures ◦ Leads students step-by-step to a solution ◦ Explains how to work through the problem
Evaluate	◦ Observes students as they apply new concepts and skills ◦ Assesses student's knowledge and/or skills ◦ Looks for evidence that students have changed their thinking or behaviors ◦ Allows students to assess their own learning and group-process skills ◦ Asks open-ended questions such as: Why do you think…? What evidence do you have…? What do you know about…? How would you explain…?	◦ Tests vocabulary words, terms and isolated facts ◦ Introduces new ideas or concepts ◦ Creates ambiguity ◦ Promotes open-ended discussion unrelated to the concept of skill

Instructional Model Chart – Student's Role

Steps of Instructional Model	Inquiry-Based Learning (Student Centered)	Traditional Model (Teacher Centered)
Engage	° Ask questions – Examples: Why did this happen? What do I already know about this? What can I find out about this? ° Shows interest in the topics	° Asks for the "right" answer ° Offers the "right" answer ° Seeks one solution
Explore	° Freely brainstorms ideas within the limits of the activity ° Tests predictions and hypotheses ° Develops new predictions and hypothesis ° Tries alternatives and discusses them with others ° Records observations and ideas ° Suspends judgment	° Passive involvement, allows others to do thinking and exploring ° Works quietly with little or no interaction with others unless exploring ideas or feelings when given permission by the teacher ° "Plays around" indiscriminately with no goal in mind ° Stops with one solution
Explain	° Explains possible solutions or answers to others ° Listens critically to others' explanations ° Questions other's explanations ° Listens to and tries to comprehend explanations that classmates and teacher offer ° Refers to previous activities ° Uses recorded observations in explanations	° Proposes explanation from "thin air" that is not relevant to previous experiences ° Brings up irrelevant experiences and examples ° Accepts explanations without justification ° Does not attend to other possible explanations
Elaborate	° Applies new labels, definitions, explanations, and skills in new but similar situations ° Uses previous information to ask questions, propose solutions, make decisions, and design experiments ° Uses evidence to draw reasonable conclusions ° Records observations and explanations ° Checks for understanding among peers	° "Plays around" with no goal in mind ° Ignores previous information or evidence ° Draws conclusions from "thin air" ° In discussion, uses only those labels that the teacher provided
Evaluate	° Answers open-ended questions using observations, evidence and previously accepted explanations ° Demonstrates an understand or knowledge of a concept or skill ° Evaluations his/her own progress and knowledge ° Asks related questions that encourages future investigations	° Draws conclusions, not using evidence or previously accepted explanations ° Officers only yes or no answers and memorized definitions or explanations as answers ° Fails to express satisfactory explanations in his/her own words ° Introduces new, irrelevant topics

National Science Education Standards

Teaching Standards

Standard A: Teachers of science plan an inquiry-based science program for their students.
Standard B: Teachers of science guide and facilitate learning.
Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning.
Standard E: Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

Content Standards

The eight categories of content standards are

- Unifying concepts and processes in science.
- Science as inquiry.
- Physical science.
- Life science.
- Earth and space science.
- Science and technology.
- Science in personal and social perspectives.
- History and nature of science.

Grades 5-8, Content Standard A: Science as Inquiry

Provide students in grades 5-8 opportunities to engage in full and in partial inquiries. In a full inquiry students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, they develop abilities and understanding of selected aspects of the inquiry process. As a result of activities in grades 5-8, all students can develop:

- Abilities necessary to do scientific inquiry:
- Identify questions that can be answered through scientific investigations
- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Recognize and analyze alternative explanations and predictions
- Communicate scientific procedures and explanations
- Use mathematics in all aspects of scientific inquiry
- Understanding about scientific inquiry (divided into seven categories)

Grades 9-12

Abilities necessary to do scientific inquiry; understand scientific inquiry.
Provide students at all grade levels and in every domain of science to have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and

techniques to gather data, thinking critically and logically about relationship between evidence and explanations, constructing and analyzing constructive explanations, and communicating scientific arguments.

Facets of Engineering

Applied Engineering – packaging, telecommunications, computer science or technical sales. Industries: energy, pharmaceuticals, automotive, manufacturing, chemicals, computer

Biosystems Engineering – combines biology with engineering. Biosystems engineers ensure safe food, healthy ecosystems, bio-energy and human health.
Research: bio-energy, biomedical, ecosystems, food safety

Chemical Engineering & Materials Science - explores the processing of materials and the production or utilization of energy through chemical reactions.
Research: energy conversion, bio-fuels & bio-chemicals, biochemical engineering, composites and materials structures center

Civil Engineering - serves society by designing the built environment and managing the natural environment. You will learn to plan, design, and construct civil works like highways, water and wastewater systems, tunnels, dams, buildings, and bridges.
Research: water resources modeling, structural fire resistance, high performance structural and pavement materials, water and waste water treatment

Computer Science and Engineering – deals with information and computation. It is also the art and science of designing, implementing, testing, and maintaining complex software systems for a variety of areas including business, engineering, and gaming.
Research: embedded intelligence, robotics, digital evolution, data mining, pattern recognition, image data processing

Electrical and Computer Engineering - includes the study of electrical and electronic circuits and devices, power, communications, signal processing and systems control.
Research: robotics and control, biomedical engineering, micro/nano electronics, materials and devices, electromagnetics, energy and power systems, computer architecture and embedded systems

Environmental Engineering - involved in water and air pollution control, recycling, waste disposal, and public health issues. Environmental engineers conduct hazardous-waste management studies in which they evaluate the significance of the hazard, advice on its treatment and containment, and develop regulations to prevent mishaps.
Research: Environmental impact of proposed construction projects, analyze scientific data, and perform quality-control checks. Environmental engineers are concerned with local and worldwide environmental issues, including protecting water quality, global warming, automobile emissions, and ozone depletion.
NSF Center for Microbial Ecology, NSF Center for Integrated Toxicology

Mechanical Engineering - applies fundamental principles of mechanics and thermodynamics to design. Mechanical engineers are involved in the design, manufacture, and testing of essentially every product of modern society.
Research: cardiovascular and orthopedic mechanics, vibrations and controls, manufacturing and advanced cutting tools, composite vehicle research, energy and automotive research

Resource: http://www.egr.msu.edu/future-engineer/what

Step-by-Step How to Plan for a Science Fair Expo

Delegate as much as you can!

Step 1: Set a date. Find a Location.

1. Check with the principal, district office and other teachers to make sure that you do not conflict with city, state or national expos. You want to hold your expo at least a couple of weeks before the larger expos. This way your students can participate in them.

   If other teachers want to participate with their classes, then act in consort to plan this event. If you are planning the expo for the whole school, you will need a whole day for the event.

2. The place you hold the expo will need to be large enough to accommodate all of the display boards and have outlets for computers at a specific location in the room(s).

   NOTE: A display board is about 36" wide when all 3 sides are open. A table will usually accommodate 4 display boards, 2 back-to-back on a 6' table.

   - A large high school gymnasium is a good location and you will not have to pay a fee.
   - Library
   - Your classroom – can usually accommodate your class and another teacher's students.
   - Cafeteria – if your expo is scheduled after school.

Be sure to include the school principal in the decision-making process.

Step 2: Make a schedule for the Expo.

NOTE: Start this step at least one month before the event.

Write a temporary schedule. Prepare for Murphy's Law!
Here are some questions to guide you…

- Will you need to prepare the room or will custodians do it for you?

- If you need to prepare the room, how early will you have access to the room to set it up?

- Who can you get to help you to set up?
  To check the students in when they arrive at the expo? (Parents, students, teachers)

- When will you have the students set up?

- Are you going to invite parents? Family members? This is a big event in their kids learning. And believe it or not, it is good publicity for the school!

- Will you invite other science classes?

Idea: Your class can set up their display in the morning. Have an open house for the other classes in the school for a couple of hours and have the parents come after school or in the evening.

- If this is a school wide science fair expo, do you want to sell items at the check-in counter as a fund raiser? If so, what would you sell? T-shirts, bake-sale, raffles to pay for prizes, etc.

- Are you going to hand out award certificates?

- Are you going to award a physical prize? Maybe some local stores would like to contribute a prize? Or call up a few science kit supply businesses and ask them. Don't be shy. It has worked for me. Tell them you are going to send out a media release to the newspaper and mention their contribution in the release.

  Are you going to do a public announcement of the winners? Will you need a speaker system?

- If you do not know how to write a press release, then go to www.prweb.com They have a free tutorial.

  If you have a very good writer in the school or family, ask them to write the release for you. Send it out 2 weeks to 1 month in advance and then ask the local newspaper to list it in their local events - both print and online.

- Who are going to be the Judges? Remember to schedule a time at the Fair for Judging and an Award Ceremony.

  If your class is displaying their science fair project, I suggest that you not be a judge.

  Do you have a score sheet for the judges to use? If not, you can use or modify this one.

Step 3: Who are you going to invite to the Expo?
Since your students are putting forth so much effort and this is their celebration, why not ask the class to brainstorm who they want to invite and how to contact them? This is another opportunity for them to learn a skill that they will be able to use throughout their lives!

Here are some ideas to add if the students did not come up with them:

1. For teachers and students who are not participating in the Science Fair
   - Make a flyer and put it around the school.
   - Announce your expo at a teacher's meeting.
   - Place an announcement in the school calendar, newsletter, and website.
   - Make the announcement one month before the event.
   - Send a memo or email a notice.
   - **Do all the above!**

2. School administrators, school district officials including Superintendent of schools, librarians, athletic coaches, secretaries, and other support staff including maintenance people and their families.
   - Do all the above one month before the Expo/Olympiad.

3. Parents of the participants
   - Send a Science Fair Expo Participation Reminder for Parents two weeks before the event. Send a flyer and email a notice. Place another announcement on your web page.

4. Be sure to invite the Press.
   NOTE: Is all the information on the flyers and emails correct: location, date, time?

   Email Invitation: Ask the class to help you to write an email. Ask for a volunteer to write on the board or newsprint. What details do we need to include? (who, what, where, and when)

   Sample email

   > We are inviting you to our (**class, school**) Science Fair Expo (Olympiad) on (**date**) from (**time**) to (**time**). We are so excited to share with you (**number of participants**) experiments and display boards that we have worked on for the last (**months, weeks**).
   >
   > [In teacher's email]
   > You can schedule your class for a 30-minute visit. A sign-up sheet is outside our door.
   >
   > We welcome administrators and district officials at any time. Parents are welcome any time during the day as well as after school or evening.
   >
   > We are looking forward to you coming and asking us questions about our Science Fair Projects.
   >
   > Respectfully,
   >
   > **(Class of, School)**
   > (address of school, class location in the school)

   (You can also ask a couple of students to go from room to room to schedule the students and their teachers).

Step 4: Plan the layout of the room

1. Make a layout of the room using graph paper. Measure the following dimensions:
   - length and width of the room
   - length and width of the tables
   - size of the display board when all 3-panels are open.

2. Decide how many tables you are going to need.

3. Decide how you want to arrange the tables. Most expos have tables set up in rows with walking room between the rows.

4. Line tables up along a wall for those who need computer hook-ups.

5. Meet with the custodial staff and administration to go over the details. This is a must because of insurance and union rules.
    - Locking your room. Opening and closing the school if you are going to have the Fair after school hours.
    - Room set-up and take-down. Who will or can help you?
    - Best way to not cause disruption to other classrooms.
    - School check-in security procedures.
    - Where and how to obtain additional tables.

6. On your layout sheet
    - Assign a row of tables (or section of tables) for each facet of engineering. Make a sign that will be visible to the visitors.

    - Label each row of tables with a letter. Make a sign. That way this letter will be easily visible to the visitors.

    - Assign each space a number.

    - Make several copies of your layout design for students, volunteers who are going to set up the room, and keep the layout on display for visitors.

      When students check in the day of the Fair they will be given a pre-assigned row and number where they will set up their displays.

Step 5: Tracking System for Science Fair Volunteers Printable

The best volunteers are your students, if old enough, and parents.

Schedule Sheet

Activity	Volunteer Assignments	Backup Volunteers
Room Set-Up	2) Name: Phone: Assigned Time: 3) Name: Phone: Assigned Time: 3) Name: Phone: Assigned Time:	1) Name: Phone: Assigned Time:
Assist at Science Fair • Help students set up their projects • Assist in checking to make sure compliant with safety rules. • Monitor event • Direct traffic • Sit at welcome table. • Take photos of kids and their display boards • Find experienced (when possible) volunteer Judges	1) Name: Phone: Assigned Time: 2) Name: Phone: Assigned Time: 3) Name: Phone: Assigned Time: 4) Name: Phone: Assigned Time:	1) Name: Phone: Assigned Time: 2) Name: Phone: Assigned Time:
Take-down and reset the room to original order.	1) Name: Phone: Assigned Time: 2) Name: Phone: Assigned Time:	1) Name: Phone: Assigned Time:

Step 6: Send home the final Science Fair Expo Reminder

Step 7: Day of the Science Fair or Day before

- Ask the students, volunteers and custodial people to help you set up the room.

- **Day of the Fair**:
  - Remind volunteers at the greeting table to check-in students, give them **the row letter and space number** where their display will be set up.

  - Ask volunteers to walk around the room and ask if anyone needs help.

  - Remove the following, but first explain to the child and parent the reason it has to be removed. Remind the volunteers of the hours of student preparation and to be sensitive as to how they will feel.

    - ✓ Flimsy display boards that can fall over and injure someone.
    - ✓ Animals. No animals are ever allowed at a Science Fair.
    - ✓ Chemicals and liquids in open containers.
    - ✓ Wiring hazards such as frayed insulation, exposed wires that people can trip on, or loose connections.
    - ✓ Foul-smelling or allergy-provoking substances such as molds in open containers.

- Be sure that you have a photographer. If you are a middle school teacher, ask the high school to suggest a student photographer.

- Do not assign yourself any tasks. Have a volunteer in charge of the volunteers. Your job is to roam the room to make sure that everything is in place and that no one tries to take another's belongings out of the room.

- Publicly award the winners of the science fair.

After the Fair is Over

- Ask the volunteers to return the room to its normal appearance.
  Have all the children take home their display boards and other belongings.

- Evaluate the Science Fair Program from beginning to end.
  1. Did all the students turn in and complete their science fair project? If not, why not and how many? Make an appointment with those students and find out what really happened.
  2. Have your students write an evaluation of the program. Ask for suggestions for next year.
  3. How did you grow as a teacher? What would you do differently next time?
  4. How many visitors came? How many classrooms came? How many parents came?

Parent's Letter

Copy and paste into a new document. Adjust it to your circumstances.

Dear Parents: Date: ______________________

Your child's classroom is doing an engineering science fair project. Each child will have an opportunity to experience the joy of discovery. At the same time, they will be engaged in the complex process of the Engineering Design Process. Participation is mandatory.

All students will have the chance to pick a facet of engineering that is of interest and do a science fair project. Children will be placed on a team which will be determined by the facet of engineering s/he chooses. There will be 3 to 5 members on each team.

When starting a science fair project, the team chooses a problem or need that they will invent or reinvent a solution for by writing a Problem Statement. Then they do library and Web research to gain the background information needed to formulate a Design Brief.

Using time management and project planning, each team and individual on the team will take on the responsibility of completing a project over a ___ week period. After designing a solution to a particular problem, team members will write a project report to summarize the background research, method of solving the problem, and data conclusions.

We will lead your child, step-by-step, through each process, so that your child has every chance to succeed as well as develop enthusiasm for scientific discovery. To complete some of the steps, your child will have homework assignments. Team members are encouraged to complete their homework together on Zoom, Google Meet, Facetime and whatever other programs are available for free. We will review the assignments at key checkpoints along the way, so that you won't face helping your child do a project the last night before the fair!

Second, we have enclosed a basic guide of how to help without getting over-involved. **We are also looking for parents to volunteer to help be a coach for a team and with the Science Fair**.

To get started, read through this packet: Student Science Project Schedule and Guide to Science Fair Projects.

If you have any questions, please email me at ____________________

Phone: ____

Up-to-date information is located on our webpage: ______________________

I volunteer to be a mentor ____

Please print your name and phone number.

Handout at Parent/Teacher Night

Information on the Scientific Method

All science fair projects include the eight steps of the engineering design process. See the chart, *How to Help at Each Step* which is included in this guide.

Time Management

In class your child is going to make a schedule with a unique timeline. It will list all the expected dates of completion for each step of their project. Included in your packet is a copy of the Timeline.

Help your child complete the tasks assigned by allowing time to go to the public library and to work with his/her team. If there is a conflict with family vacation and events, please contact me so we can work something out and still keep your child on track.

Science Fair Contest

Your child is invited to enter the Free, International Online Science Fair Contest. See details: www.super-science-fair-projects.com/science-fair-contest.html

How to Help Your Child

As stated in the letter, this is probably the longest and most intense project your child will take on in the elementary grades or high school. With other school and family obligations, even the best student can get overwhelmed, or hit a "roadblock" and lose the ability to stay on track or even finish their project. Fun and creativity comes to a halt.

Enthusiastic patience is the key without *saving* your child by stepping in and doing his / her project.

Science Fairs are annual events where students are encouraged to carry out scientific investigations. At some science fairs, students also compete for various levels of recognition.

Whether or not your children win recognition or go on to a regional, state or national competition is not the focus. **What is important is that your children believe in their greatness by experiencing small successes along their journey.**

It is in the *practice of science* that they learn to approach life's challenges in a systematic way. This is what this event is really all about.

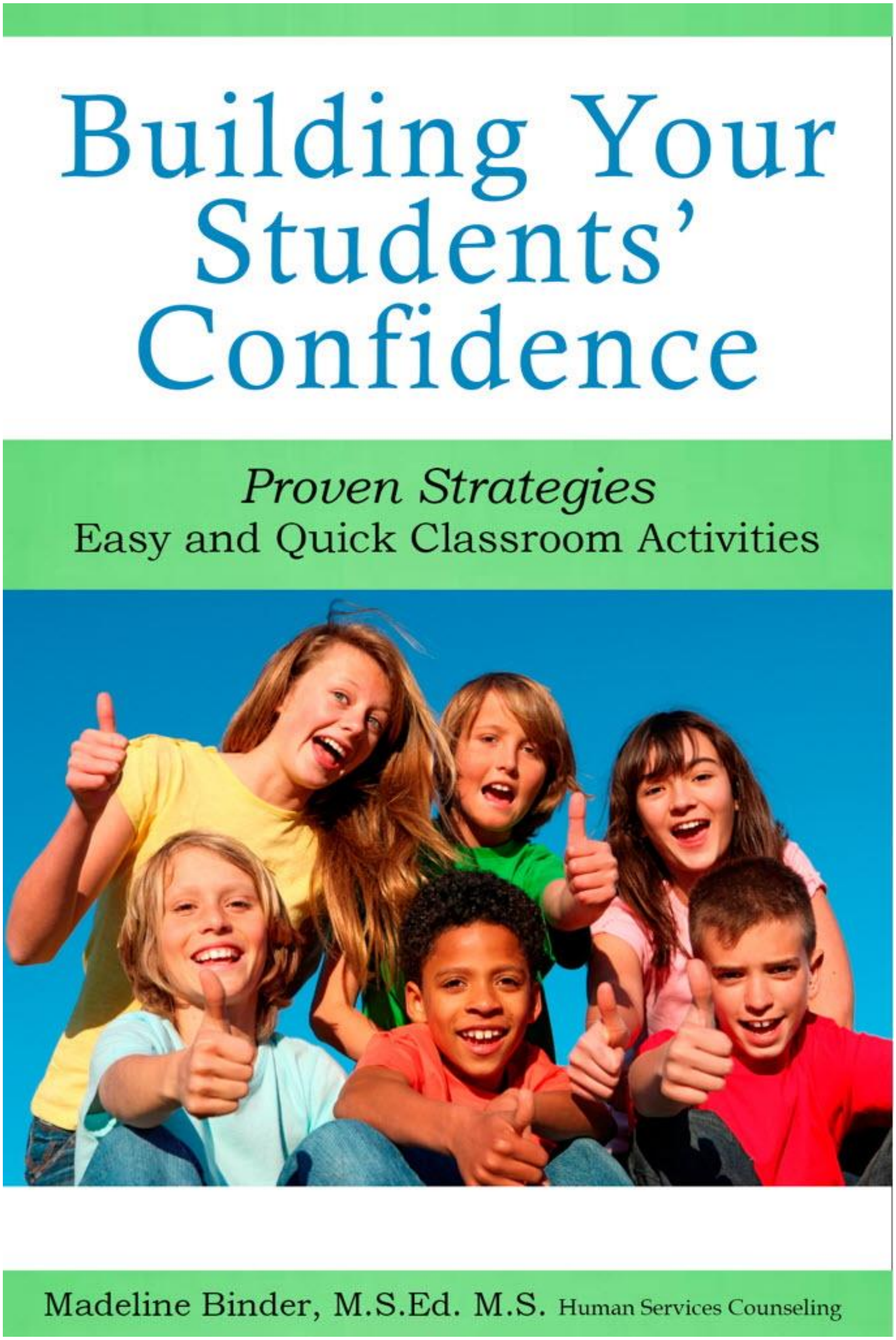
Safety Guidelines

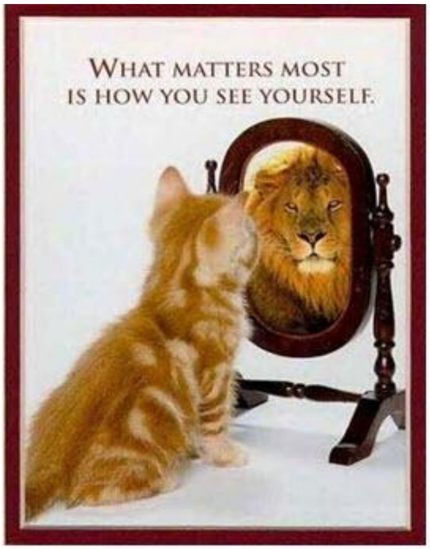
https://www.societyforscience.org/isef/international-rules/display-safety-rules/

How Parents Can Help at Each Step

Project Step	How to Help	Do Not....
Step 1. **Ask a Question**	Discussing with your child whether a project idea is practical. Network and give names of experts to interview.	Pick an idea and project for your child. Your child needs to choose their own project so they stay excited. S/he must own this project.
Step 2. **Doing background research**	Be your child's chauffeur. Transport him / her to and from the library. You can help your child think of keywords by asking "what" questions. "What words do you think will lead you to information on this topic?"	Doing the keyword or Internet search. Printing the articles and links.
Step 3. **Write a hypothesis**	Ask how the hypothesis relates to the experiment the child wants to do.	Writing the hypothesis yourself.
Step 4. **Test the hypothesis by doing the experiment.**	Assisting in finding supplies and materials. Monitor safety. Only help to build something if your child asks for help. Only help with unsafe steps.	Writing the experiment procedure. Doing the experiment. Telling the child what to do.
Step 5. **Analyzing data and drawing conclusions.**	Ask your child, "What would be the best way to record the data?" You can remind your child that the data needs to tie back to the hypothesis and used when drawing conclusions.	Create the spreadsheet. Make the graphs & tables. State the conclusion.
Step 6. **Communicate results.**	Allow your child to write his/own report alone! When practicing his presentation for the judges be an enthusiastic member of the audience. Display board: Transportation expert! **Be an admirer!**	Hands off materials, supplies and the display board! Do not mention ideas for color scheme or placement of graphs, table, data or objects.

TEACHER'S BONUS Book





Self-esteem is everything.

- It is a person's "belief" in him /herself that is most important.
- There is nothing that can stop a person if they believe they are unstoppable.
- Your students can do anything they set their minds to.
- As a teacher you set the stage for their success.

Have the children start a journal. This is different from the Design Notebook. Use a 3-ring notebook so children can put their papers in the notebook every day.

Very young children can draw their responses as you read the questions. Give them time to express themselves.

Children who can read may also enjoy illustrating their writings.

Make a card for every student and give it to them to place in the front of their journal.

I can do ANYTHING because I believe I can!
I am UNSTOPPABLE!

Have the class stand up at their desks, and with conviction, have them read what is on the card. After a couple of days, they probably will not need the card. Your job is to encourage them to say the saying with honest emotion.

Ask these questions each morning before you begin teaching.

The purpose of the exercise is to set a positive tone for the day and to have children learn to focus on the positive aspects of their lives. Studies have shown that it takes 21 days to change a behavior. Be patient!

The first time I did this it took me 3 months! Hang in there!

The Daily Activities Printables
Make copies for each student. Hand out one sheet first thing in the morning and do the activity. While the students do the exercise, you do the same. Keep your own journal.

Choose one feeling per 21 days.

- For instance, the first worksheet has the children focus on being happy. Do the Happy worksheet for 21 days.

- The second worksheet focuses on being grateful. Do that worksheet for 21 days.

  Have the kids put the papers in their desk and tell them they are going to use them at the end of the day.

  10 minutes before school is over for the day, have the kids take out their sheet of paper and complete the **End of the Day Questions**. Collect them. After the kids leave for home or in the evening, read the activity papers and put a positive comment or fun sticker at the top of the paper. The purpose is to encourage them to be open about their feelings.

  Your students' responses are good feedback about your teaching and attitude.

  Return the papers to the students the next morning to put in their journals.

  After 21 days have your children decorate the cover of their journal for an art lesson. Provide various kinds of materials so they can freely express themselves.

  Take your students through the following brief relaxing process right before you begin your science fair project lesson. This process can take 5 – 10 minutes. I learned it at a professional meditation course I took in Chicago. It is the most relaxing process I have experienced.

Put a Do Not Disturb sign on your door. (Inform the principal in advance what you are going to be doing when the sign is on the door.)

Have all the students remove everything from their desks.

In a quiet, warm voice, speak ever so slowly. This way the students can implement each action, one at a time.

Close your eyes.
Put your feet flat on the floor.
Place each arm on each side of your lap, palms up.
Take a deep breath and let it out slowly.
Thank your body for its greatness.

Imagine that you have your very own golden sun that is about six feet above your head. Feel its rays slowly warming every cell of your body, starting at your

Head [pause]
Penetrating every cell [pause]
Ever so ***slowly*** moving down your neck [pause]
Shoulders [pause]
Arms [pause]
Hands [pause]
Finger tips [pause]
Chest (your heart, lungs, tissues, organs) [pause]
Stomach [pause]
Lower regions [pause]
Thighs [pause]
Legs [pause]
Calves [pause]
Feet [pause]

Allow the rays to penetrate every cell as it moves up the backside of your body, starting at the soles of your feet, ever so ***slowly***, until you reach the very top of your head.

Daily Activities Printable
Middle School thru Adulthood

Name____ Date___________

Morning Questions[2]

Question - What am I most happy about right now?
Question - What about that makes me happy?
Question - How do I feel now that I have that feeling?

End of the Day Questions

Question - What did I learn that was interesting today?
Question - What about what I did today makes me happy?
Question – What will I do differently tomorrow to bring me different results?
Question – What did I learn about myself today?

[2] Robbins, Anthony. *Awaken the Giant Within*. New York: Summit Books, 1991, page 204.

Name____________________________________ Date_____________

Morning Questions

Question - What am I most grateful about right now?
Question - What about that makes me grateful?
Question - How do I feel now that I have that feeling?

End of the Day Questions

Question - What did I learn that was interesting today?
Question - What about that makes me feel grateful?
Question – What will I do differently tomorrow to bring me different results?
Question – What did I learn about myself today?

Name________________________________ Date____________

Morning Questions

Question - What am I excited about right now?
Question - What about that makes me excited?
Question - How do I feel now that I have that feeling?

End of the Day Questions

Question - What did I learn that was interesting today?
Question - What about what I did today makes me feel excited?
Question – What will I do differently tomorrow to bring me different results?
Question – What did I learn about myself today?

Name____ Date_______________

Morning Questions

Question - What am I most joyful about right now?
Question - What about that makes me joyful?
Question - How do I feel now that I have that feeling?

End of the Day Questions

Question - What did I learn that was interesting today?
Question - What about what I did today makes me joyful?
Question – What will I do differently tomorrow to bring me different results?
Question – What did I learn about myself today?

Name______________________________________ Date______________

Morning Questions

Question - What am I most proud about right now?
Question - What about that makes me proud?
Question - How do I feel now that I have that feeling?

End of the Day Questions

Question - What did I learn that was interesting today?
Question - What about what I did today makes me feel proud?
Question – What will I do differently tomorrow to bring me different results?
Question – What did I learn about myself today?

Primary Grades

Name____________________________________ Date_____________

Morning Question: What makes me happy this morning?

End of the Day Question: What am I happy about right now?

Name___________________________________ Date_____________

Morning Question: What makes me grateful?

End of day question: What makes me grateful right now?

Name____________________________________ Date_____________

Morning Question: What makes me excited?

End of day question: What makes me excited right now?

Name____________________________________ Date_____________

Morning Question: What makes me enthusiastic?

What made me feel enthusiastic today?

Name___________________________________ Date_____________

Morning question: What makes me proud?

What makes me feel proud about what I did today in school?

Name___________________________________ Date_____________

Morning Question: What makes me joyful?

End of day Question: What makes me feel joyful right now?

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

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I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

I can achieve whatever I want to! I am UNSTOPPABLE!

Today is the beginning of the best day of my life!

Today is the beginning of the best day of my life!

Today is the beginning of the best day of my life!

Today is the beginning of the best day of my life!

Today is the beginning of the best day of my life!

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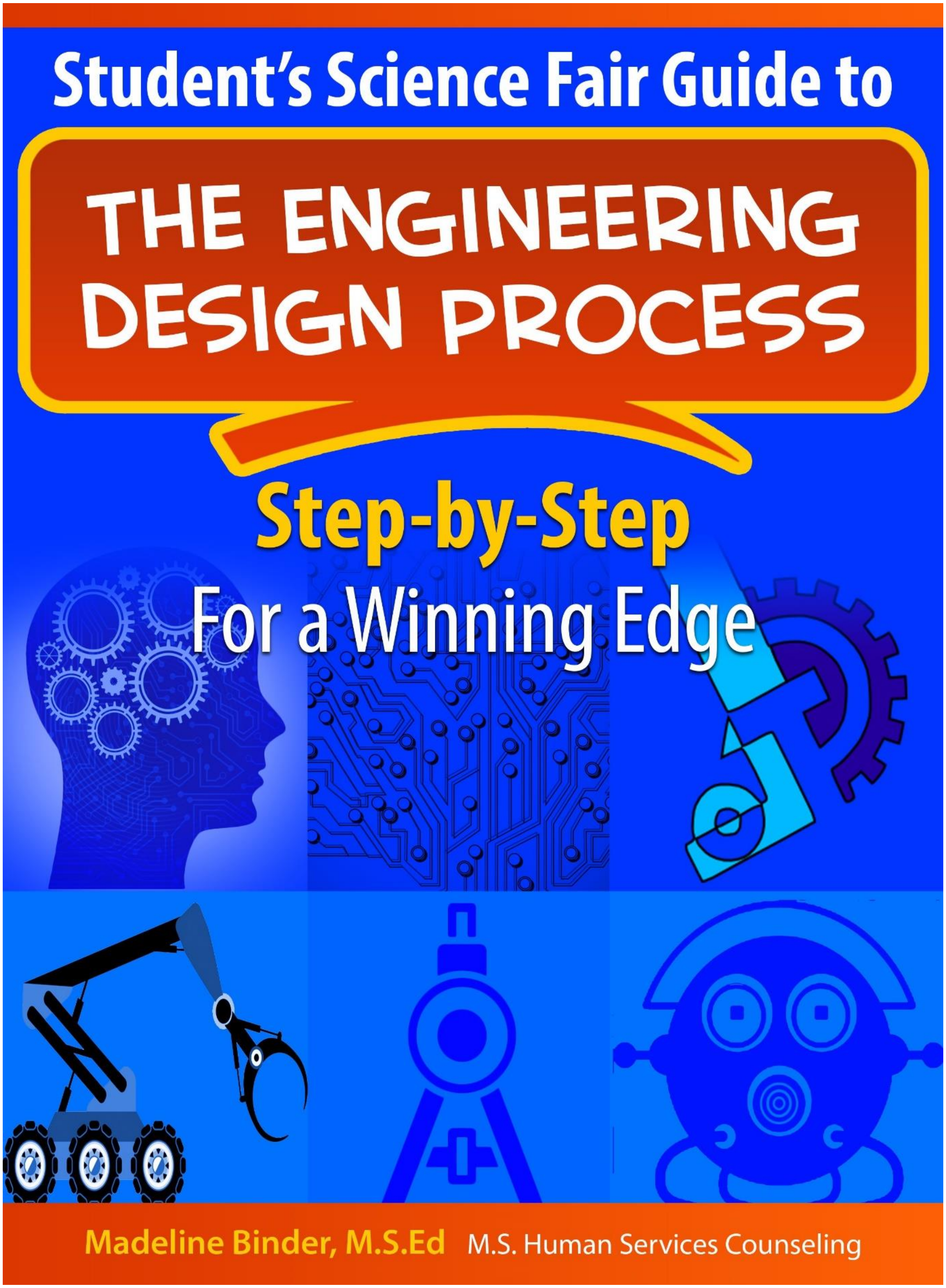
STUDENT'S GUIDE



BEFORE YOU BEGIN

How to Use This Book

Letter "AJ" on the Timeline

Color Coding of the Chapters

Each section of the book has titles and subtitles. For instance, this chapter has different shades of red and orange. We formatted the color coding to help you to easily follow each section.

Sequential Order

The ideas in *Student's Science Fair Guide to the Engineering Design Process* are to be read in sequential order.

Step 1: Print the Table of Contents (TOC). Use it as a guide and checklist.

Step 2: Look in the Table of Contents in the section, Appendix, for a list of all the Printables. Print 4 copies of the Bibliography printable and print 1 copy of all the other Printables. Place the printed pages in a folder.

Step 3: Leisurely read the book from beginning to end. This will give you the whole picture of the process.

Step 4: Read all the rules for your school's science fair. They take precedent over what is written in this book.

Step 5: After you have read the whole book, cover to cover, go back to the beginning of the book and work the process… step-by-step.

- At the end of each section is an "Outcomes Checklist". (*Outcomes* are explained later.) Print each Checklist page. Do not move forward to the next section until you complete each outcome on each of the lists.
  - As you finish each section, make a check in the box on the Complete Engineering Design Process Checklist sheet that you printed.

Step 6: After you have completed your science fair project, put everything together for your science fair. Go back and check off each section using a different color ink or pencil.

Outcomes for this Book

1. Know how to decide upon a project that will keep you interested and enthusiastic throughout your science fair project.

2. Know the 8-Steps of the Engineering Design Process.

3. Know how to complete a long-term project from beginning to end.

4. Be armed with extra tidbits from the SECRET FILES to give you a winning edge.

Good luck and enjoy the process.

Overview for this Section of the Book

WOW! Your teacher announced that your school is going to have a science fair and students are responsible for exhibiting their project. What did you feel? Enthusiastic? Despondent? Dreadful? Fearful? Excited?

Whatever you are feeling now, don't worry because this book is designed to walk you through the world of science fair projects, step-by-step. Yes, this book is for **YOU**! Follow the pages, one at a time. Take time out when suggested so you do not get overwhelmed.

You may be thinking that not everyone likes doing a science fair project. I understand. A student can't like every subject or assignment. BUT a science fair project is a MUST at your school. What is the secret of enjoying this assignment?

SECRET FILES #1

Choose the subject that interests you.

Another secret is to imagine you are a detective. Search for clues to solve the mystery of doing a science fair project.

In the Appendix there are over 50 questions and design ideas that will promote engineering science fair projects that you can consider. Scattered throughout the book are a few project ideas, motivational quotes, and helpful clues.

If you haven't been to a science fair you are in for a big surprise. It is a really fun and exciting event. In the Appendix you can to see what a science fair looks like.

Remember to watch for the

SECRET FILES

Here is your first motivational quote…
Success is a Journey – Ben Sweetland

SECRET FILES #2

A Winning Science Fair Strategy

Every idea begins with your attitude and thoughts.
What you believe will happen, will happen.

Principle of Quantum Physics

Before you conceive of what you want to do for a project, let's read a story. It is a metaphor. What is a metaphor? It is where you take one idea and use it for another idea.

Let's say you are going on a vacation to Disneyworld. Does your enjoyment come only after you arrive? Not by any means. Your joy comes the moment you and your family decide to take the trip. As you look at the descriptive brochures you feel a thrill of anticipation even before the journey starts. Then you begin to visualize yourself participating in all the fun-filled activities.

Are you starting to get excited?
Let's read on . . .

Does the enjoyment end when your vacation is over? Not a bit. You'll have the pleasure of telling your friends of your experience, looking at the photos you took, and reminiscing about all the fun you had.

Can you imagine the feeling of accomplishment once you see your project come alive in photographs after the fair?

The same is true for the adventure of coming up with a Science Fair Project. The moment you say, "*I am going to think of an outstanding science fair project*," you have already begun your successful journey.

Here is a little understood fact. *You are a success the moment you start on the road to success*. You gain happiness after taking the first step towards success. Therefore, you do not have to wait until you determine which science fair project you are going to dream up, nor for the project to be completed before you are a success. You can be a success right now! IF you **BELIEVE** this is true, it will be true.

OK, are you ready to stop reading, and start doing? Let's follow the clues to find a science fair idea that is just right for **YOU**…

Now…this is usually where a really HARD question springs-to-mind:
WHAT are the best projects to do?

And there's really an **EASY** answer…
Choose the science project **YOU LIKE** – because with science projects it's **THE DOING** that really counts the most! So, don't get anxious…. get excited! Science fair projects are fun!

What do detectives do to solve a mystery?
Ask questions, look for clues and discover answers.

What do Detectives do when faced with challenges?
Believe THERE IS ALWAYS A WAY!

Science Fair Projects are about investigating and solving mysteries; exploring topics, brain-storming ideas to find answers to questions or inventing a solution to a problem. **AND** about **NEVER GIVING UP**!!!

What is the Mystery that you are really, really, really interested in solving?

What clues will you turn up when you investigate your project?

What answers will you uncover when you solve the mystery of science fair projects?

Are the answers what you suspected them to be?

Are you ready to begin your investigation? Here we go!

Timeline

Difference between a Goal and an Outcome

Background Information for Timeline

Letter "AI" on the Timeline

SECRET FILES #3

A GOAL is something you are aiming for, something you would like to achieve.

AN OUTCOME IS SOMETHING THAT WILL ABSOLUTELY HAPPEN. An outcome is something that your brain believes you already achieved.

Why is the wording so important?

Because what we say determines how we feel. Feeling you have accomplished something helps to reduce fear, anxiety – and most important – gives you a positive feeling of pride in your achievement as if it already happened.

What is a Timeline?

A timeline is a simple, effective plan of action that outlines what you must do in order to meet your outcomes. It shows the dates and completion of each step of your project.

To produce consistent results, you must manage your activities. The timeline gives you the tool to manage your time, energy, focus, and talents so you can thoroughly enjoy doing your Project.

Why Bother with A Timeline?

Small step-by-step actions, consistently taken over a period of time, have a giant impact. – Anthony Robbins

You must be able to manage your time and priorities because it takes 2 to 3 months to complete an excellent science fair project. You can have the best intentions (goals) to complete a project, but if you do not have a means of organizing yourself, time gets lost because of a failure to manage time and priorities. You could lose focus and direction.

A Science Fair Project requires specific step-by-step actions taken in a particular order. When the Judge(s) read your Design Notebook, looks at your display board, and asks you questions about your project, they check to make sure that you have included every step of the process. You MUST KNOW the steps you took as well as the results…

KNOW this information like you know 1 + 1 = 2.

How Do You Use the Timeline?

You will plot the **OUTCOMES** on the vertical line and their respective dates of completion.

Take the printed Timeline template and directions from the folder.

After you have completed putting the dates on your Timeline, attach it to the inside cover of your Design Notebook.

Keep the Design Notebook in a safe place. It will hold all the secrets to your science fair project investigation.

Shopping List 1

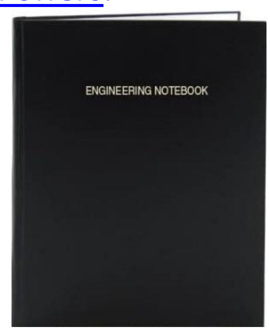
Materials to Purchase

Letter "AH" on the Timeline

First read about these materials before making a purchase. Detailed information follows on the next few pages.

1. **For Background Research and Bibliography Note Taking**
   1 pkg white, 4 pkgs each a different color, 6" x 8" lined or plain note cards

2. Design Notebook – Look at the different kinds of Engineering Design Notebooks that Amazon.com offers.



3. Day-Timer – I recommend the pocket size 2 page per day indexed style.

4. Tabbed sections –Repositionable, for the Design Notebook and for the Project Report

Engineering Design Notebook

Be Diligent in Keeping Your Notes

Letter "AG" on the Timeline

Overview

An engineering design notebook is the single most valuable tool for any engineer, whether they are seasoned professionals with years of experience or students doing a project for the first time. The notebook is a permanent record of all you've done to create and complete an engineering design project.

During the course of your project there will be dozens of details to keep track of. That is the reason for keeping a daily record of your project. If you are diligent about documenting everything you do and think about, and everything that happens as a result of your activities, you won't have to worry about doing a redesign of your prototype (if necessary) or forgetting something later when you write your report.

Your teacher will expect you to hand in your Engineering Notebook with your report. When you enter a science fair you will be expected to display this notebook on your table. The Judge will possibly go through the book and ask questions.

For your investigation, you will need a ***NEW*** notebook in which you will take notes as you do your investigation. Everything you do for your project will be kept in this notebook as well as tracking your thoughts, feelings questions, research and design sketches. Let's call this your **DESIGN NOTEBOOK**. Sometimes it is referred to as a Lab Notebook or Science Journal.

How to Choose Your Design Notebook

There are many kinds of notebooks, ranging from official engineering notebooks to makeshift notebooks. The table below offers a summary of different types of notebooks. Click on the link below to find the lab book on Amazon.

- Bound Composition Notebook - A bound spine (not spiral) is difficult to use because you cannot easily tear out pages. The pages do not lay flat and it is difficult to write near the margins. Easy to find at most stores.
  Students K-Middle School

- Home Made Notebook - There are sturdy notebooks with dividers already in the notebook. Make sure that the covers are sturdy and that the pages do not easily tear out of the notebook. Perforated pages tend to do that.
Students K-Middle School

- Quadrille-Ruled Notebook - This type of notebook is made up of graph paper. You write your notes in it and make your drawings. They are available with a spiral bounding or bound like a composition notebook.
Students K-Middle School

- Engineering Research Laboratory Notebook - Its sturdy construction resists wear and the binding permits the pages to lay flat for easy writing and recording. The subtle 5x5 grid is informative but not distracting, and ideal for lab lighting conditions. Designed and built by engineers.
Students Middle School – College Teachers, Engineers

Setting Up Your Design Notebook

Overview

Your Design Notebook is a permanent record of all phases of your project. Take out the Design Notebook Printable and look at it as you read through this section of the book.

Whether you use a notebook with plain graph paper or an official Engineering Design Notebook, there are guidelines you need to follow to make sure your notebook stays organized. Organization is truly the key to a successful project.

Your Design Notebook is an invaluable tool when doing your project. It is a permanent record of all phases of your project, from beginning to end. The information that you gather will be the basis of your Project Report.

It is where you keep track of ideas, comments, problems and ideas for solving them, notes, random thoughts that occur over the weeks and months of the process. It keeps all the information organized in a single place. It tracks the history of your project in sequential order – from start to finish. Whoever reads your Notebook will be able to completely understand your project and how you came up with your solution. They will be able to follow your journey through all the steps and will be able to duplicate exactly what you did. Keep it neat!

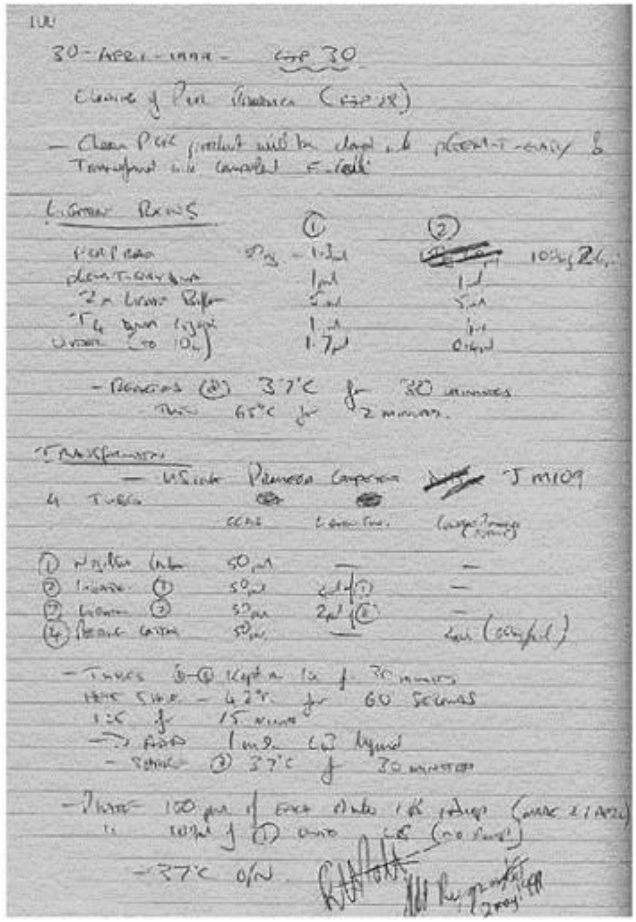
It will also be handed in to your teacher and be on display at all science fairs you participant in along with your Project Report. Did you know that the Science Fair Judge can question everything that is in the notebook?

Recording Your Entries

- **Get into the habit of writing in your Design Notebook every day.** Put a date in front of each entry, even if the entry is only a few words long. This helps you keep track of the sequence of events and observations during your project.

- **Put your name and either a phone number or email address on the inside front cover.** That way, if your notebook is misplaced or lost, the finder can more easily return it to you. You can also include the title of your project and the date, for future reference.

- **Use a non-smearing pen, and write carefully and legibly**. If you make an error, just draw a line through it and make the correction. <u>Do not use an eraser to white out</u>. (see next page)



- **Number each page of your Notebook**—it will come in handy later as you write your report. Some students organize the sections according to the steps of the engineering design method.

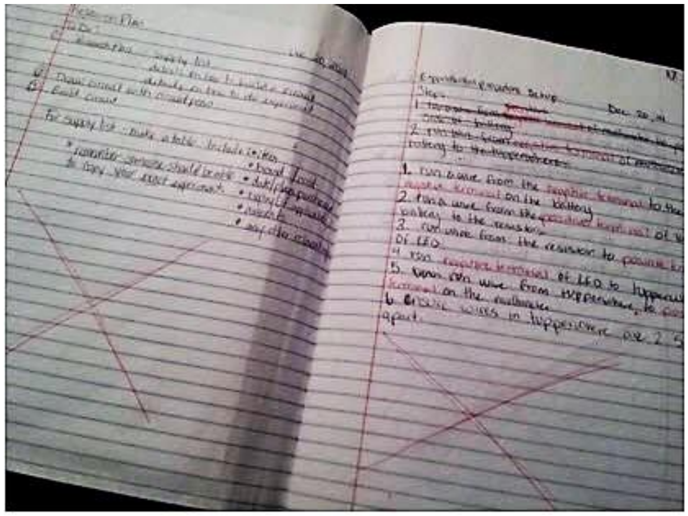
- **Date your entries**. It will help you to keep track of when you did your observations and procedures.

- **Keep the entries in sequential order.**

- **Do not leave any pages blank**. Do not go back and fill them in later. Your Design Notebook must be a record of your project every step of the way.

- **Do not remove pages from your log**. If a page is accidentally left blank, draw an X over it, but do not rip it out.

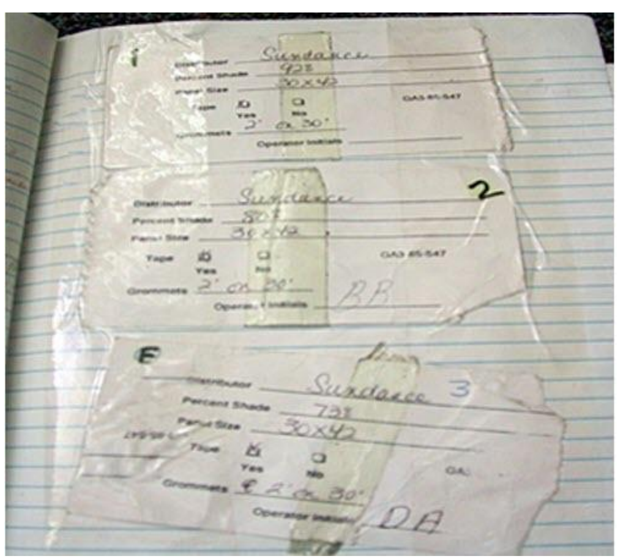
- **Leave an X in large empty spaces**.



- **Make your entries brief**. Complete sentences are not required. Entries must have enough detail so that if you go over your notes a year later you will instantly understand the entry without wondering what you meant. Whoever reads your Notebook must be able to know exactly what you did.

- **Write legibly** so you or a stranger could read it. My cursive writing is terrible. To read what I write I need to print my notes.

- **There cannot be any loose papers.** Glue, tap or staple any papers that need to be inserted in a particular place. For example, digital materials may need to be added to the Notebook. Below you can see loose pages that have been taped.



- Save a place at the front of your notebook for the **Table of Contents**, which you will create later, as you gather your data. Ask your teacher if you can use **write on tabbed sections** within the notebook, each section using a different color tab.

  Here are suggested sections:
  Timeline
  Identify & Define Problems and Opportunities
  Background Research
  Brainstorm Ideas, Generate Solutions & Choose Best Solutions
  Materials List
  Construct a Prototype
  Test and Evaluate
  Design and Refine
  Communicate Results

- **Keep your notebook handy**, especially when you are working on your project, but also when you are somewhere other than home and thinking about your project. Great ideas often come at odd moments. Sure, you can jot down a note on a scrap of paper, or try to remember the thought until you get the chance to write it in your notebook. But you won't have to worry about losing the paper or forgetting an important detail if you have the notebook with you at all times.

- Write down any thoughts that come to mind about the project.

- Note anything you need to look up later.

What to Include in Your Design Notebook
Everything! The more details, the better.

I know that I am repeating myself, but keeping accurate records that follow specific rules for entry is very important.

Since the Notebook begins at the very beginning of your engineering design project, record and date all thoughts that come to mind about the project**,** and what you hope to find out.

Record the steps, one at a time with a detailed account of your project activities. This way you will be able to go back to a previous step whenever you need to. By keeping track with such a detailed account, you will find it easier to analyze your data and write your Project Report.

Remember to staple, glue (with rubber cement) or tape all worksheets, forms and other pieces of paper. Date each entry so you know what you used it for.

The most difficult thing about keeping a Design Notebook is remembering to use it at each and every point in your project. Later, you'll be very glad that you did.

- **Brainstorming**
  The brainstorming that led you to come up with your project idea in the first place.

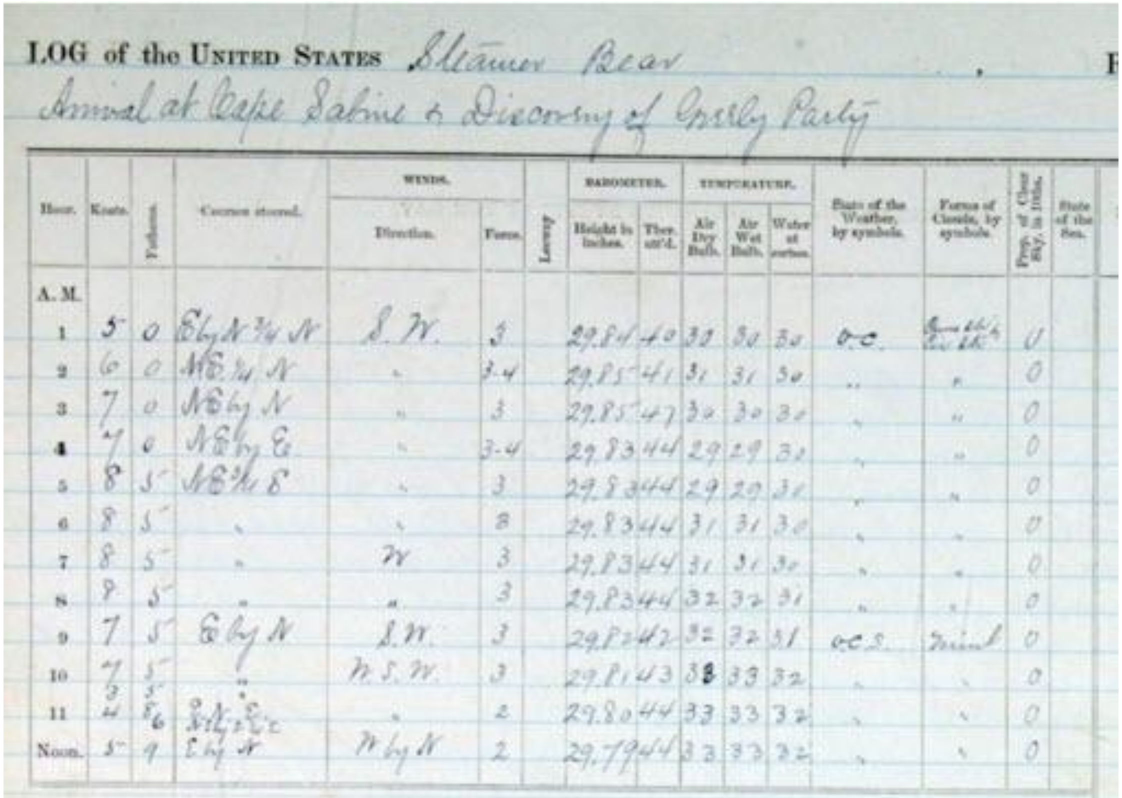
- **You will want to list**:
  - Sources you'll use in your background research, including books, articles and personal interviews. (This list automatically gives you the bibliography section of your report.)

  - Phone numbers or email addresses of everyone you contacted about your project.

  - Materials you'll need to create your invention / program. Include where to find them and an estimate of what they'll cost.

  - Design Brief, Criteria, and what you will test and measure.

  - All math calculations. Be careful to be accurate. Write all numbers, temperatures, measurements, calculations and other relevant data. If you use Excel or an electronic program, list the log dates and file names. Tape or staple the printed copies in your Design Notebook.


LOG of the UNITED STATES Steamer Bear

Arrival at Cape Sabine & Discovery of Greely Party

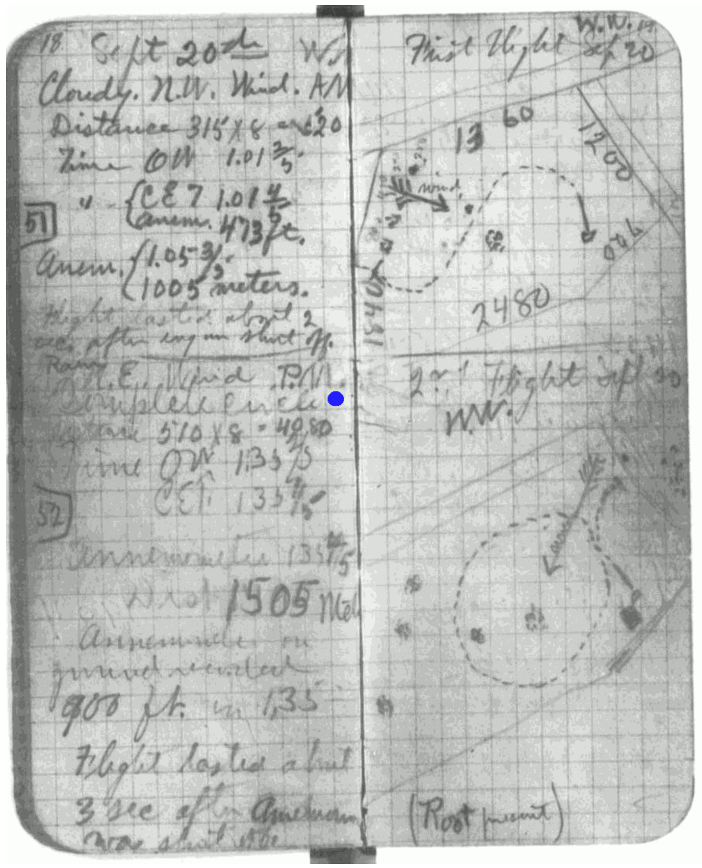
Hour.	Knots.	Fathoms.	Courses steered.	Winds. Direction.	Winds. Force.	Leeway.	Barometer. Height in inches.	Barometer. Ther. att'd.	Temperature. Air Dry Bulb.	Temperature. Air Wet Bulb.	Temperature. Water at surface.	State of the Weather, by symbols.	Forms of Clouds, by symbols.	Prop. of Clear Sky in 10ths.	State of the Sea.
A. M.															
1	5	0	E by N 3/4 N	S.W.	3		29.84	40	32	30	30	o.c.	[illegible]	0	
2	6	0	NE 3/4 N	"	3-4		29.85	41	31	31	30	"	"	0	
3	7	0	NE by N	"	3		29.85	42	30	30	32	"	"	0	
4	7	0	NE by E	"	3-4		29.83	44	29	29	32	"	"	0	
5	8	5	NE 3/4 E	"	3		29.83	44	29	29	31	"	"	0	
6	8	5	"	"	3		29.83	44	31	31	30	"	"	0	
7	8	5	"	N	3		29.83	44	31	31	30	"	"	0	
8	8	5		"	3		29.83	44	32	32	31	"	"	0	
9	7	5	E by N	S.W.	3		29.82	42	32	32	31	o.c.s.	[illegible]	0	
10	7	5	"	N.S.W.	3		29.81	43	33	33	32	"	"	0	
11	3 4	5 6	[illegible]	"	2		29.80	44	33	33	32	"	"	0	
Noon.	5	4	E by N	N by N	2		29.79	44	33	33	32	"	"	0	

- Notes of all test measurements.

- **You will want to describe in detail**:
  - Background research.
  - The procedure, including your plans, any modifications you make, and any problems or mistakes you encounter.
    - How and when you set up your trials?
    - What were your results?
    - What worked and what didn't work?
    - What did you have to go back and re-do?
  - What insights did you have?
  - What conclusion can you draw from the data you've collected, including all measurements and calculations?

- **You will want to create**:
  - A log of activities related to your project.

- Diagrams, charts, and/or drawings as a visual record of an aspect of your project. Below is Wilbur Wright's drawing.



- Drawings or photographs of your lab setup or designs (you can tape these into your Design Notebook).

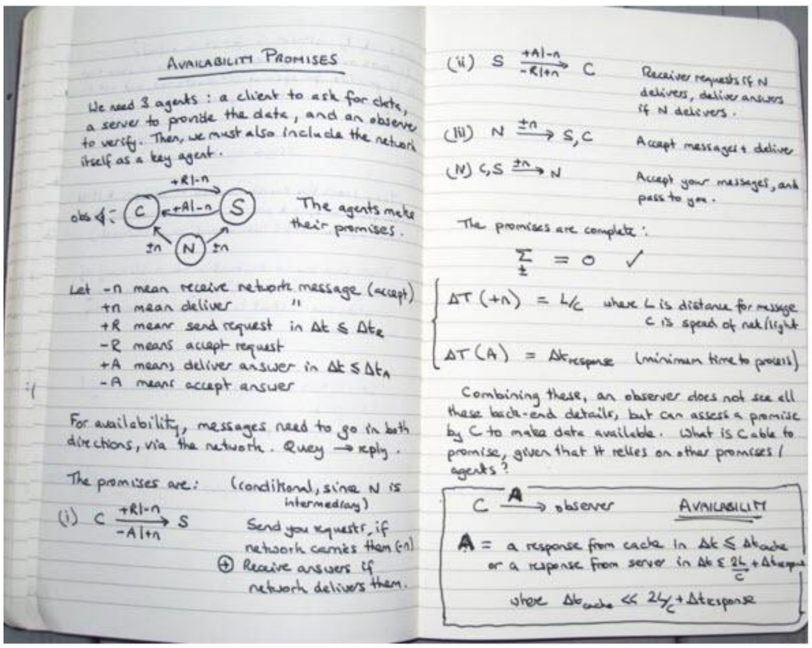
Remember to

- Put a date next to each entry.
- Keep the entries in sequential order.
- Write down any thoughts that come to you about the project.
- Make a note of everything you need to look at later.

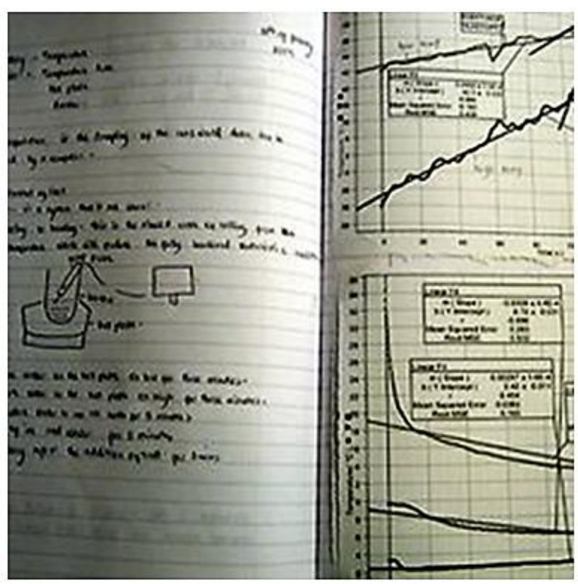
With such a detailed account of your project activities, you will be able to go back to a previous step whenever you need to. And by keeping track with such a detailed account, you will find it easier to analyze your data and write your Project Report.

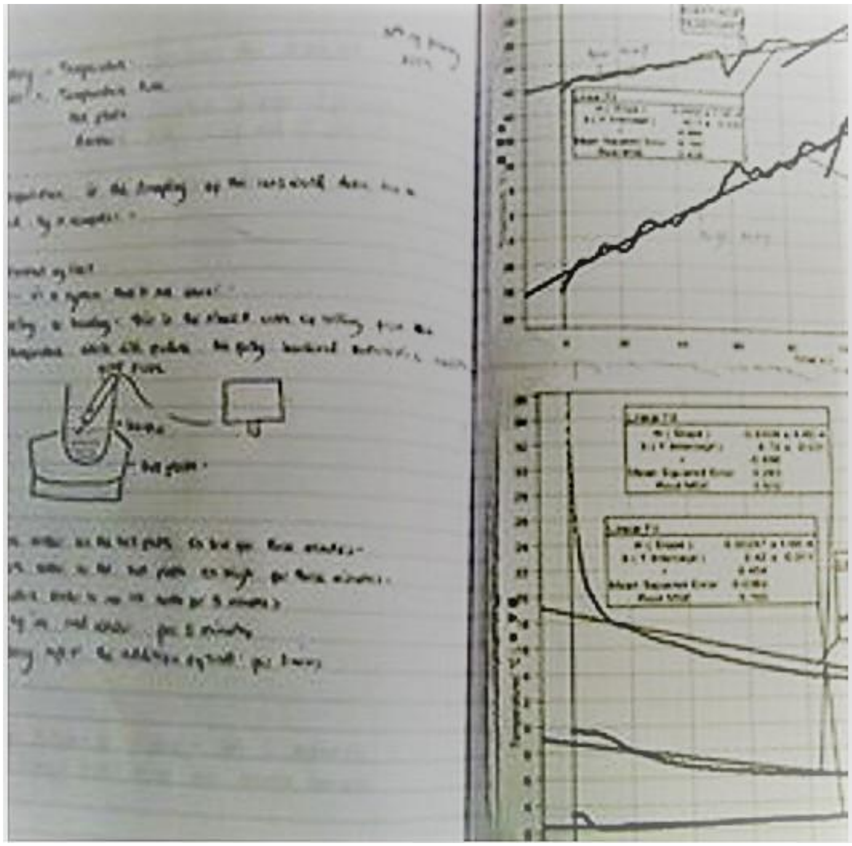
Sample of Note Taking in Lab Notebooks

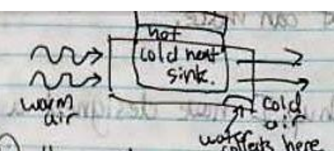
Albert Einstein



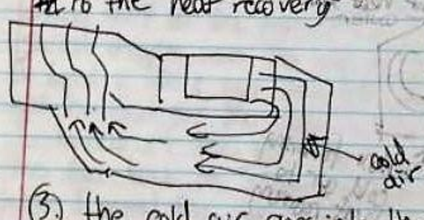
Student's Science Fair Notebooks



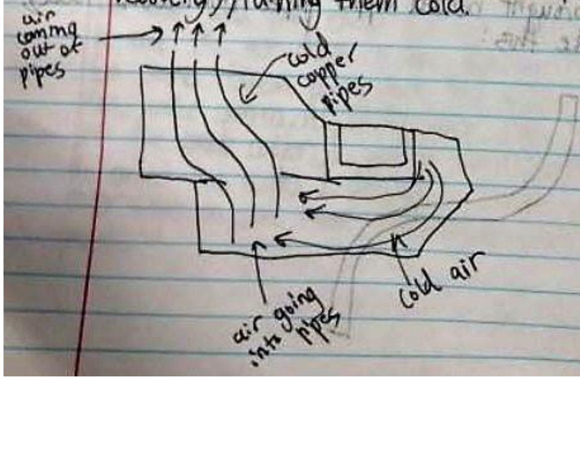




(2.) the cold air (now removed from water) is now waste, so the heat recovery box brings the cold air ~~#1~~ to the heat recovery

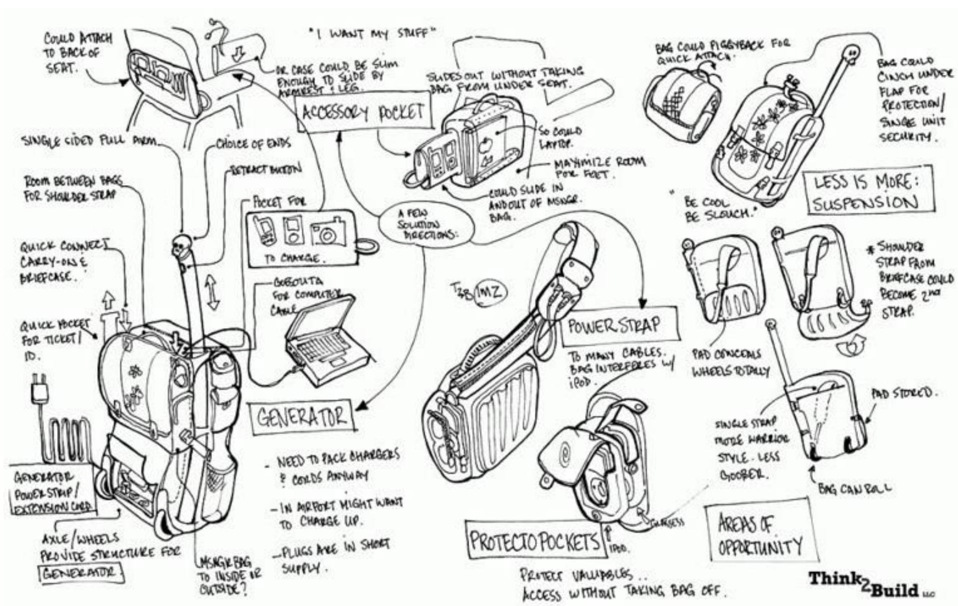


(3.) the cold air goes into the copper pipes (heat recovery), turning them cold.



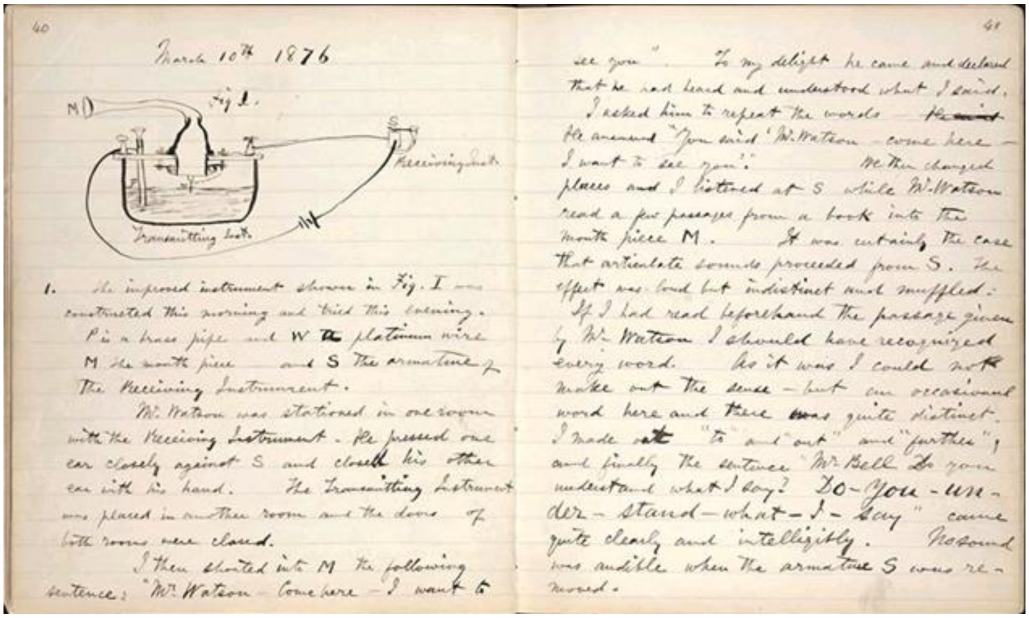
Examples of Design Notebooks Drawings

http://mrewert.pbworks.com/



https://scottthorp.wordpress.com/

Alexander Graham Bell’s Telephone Design Notebook



40

March 10th 1876

Fig. I.

M

S

Receiving Inst.

Transmitting Inst.

1. The improved instrument shown in Fig. I was constructed this morning and tried this evening. P is a brass pipe and W ~~the~~ platinum wire M the mouth piece and S the armature of The Receiving Instrument.

Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.

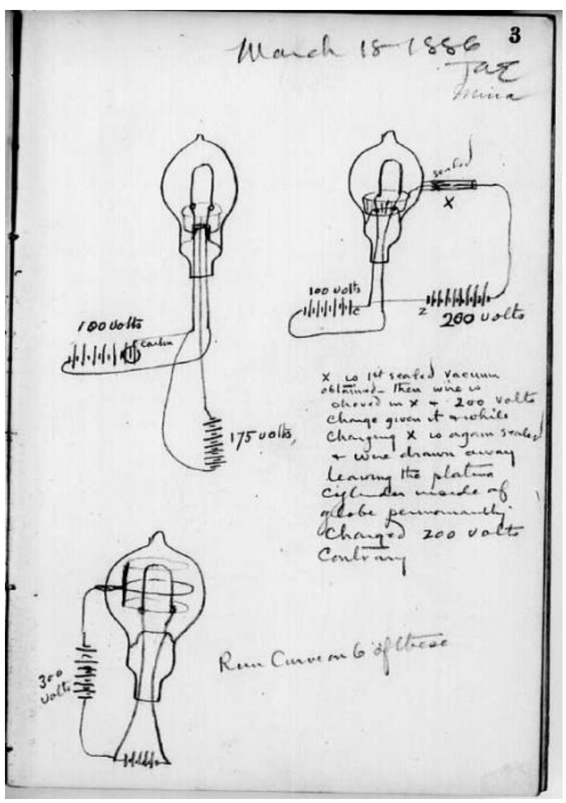
I then shouted into M the following sentence: "Mr. Watson — Come here — I want to

41

see you". To my delight he came and declared that he had heard and understood what I said. I asked him to repeat the words — ~~He said~~ He answered "You said 'Mr. Watson — come here — I want to see you'." We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The effect was loud but indistinct and muffled.

If I had read beforehand the passage given by Mr. Watson I should have recognized every word. As it was I could not make out the sense — but an occasional word here and there ~~was~~ quite distinct. I made ~~out~~ "to" and "out" and "further"; and finally the sentence "Mr. Bell Do you understand what I say? Do - you - un - der - stand - what - I - say" came quite clearly and intelligibly. No sound was audible when the armature S was removed.

Thomas Edison Lightbulb Notebook



Day-Timer

Letter “AF” on the Timeline

When you know where you are going, you are halfway there.
Zig Ziglar

One of the habits of highly effective people is keeping a Day-Timer.

What fills your day? Attending school, doing homework, participating in school activities, meeting family responsibilities and having time for your social life as well as play time… and you may even have a part-time job! Just writing all of this makes me want to take a breath!

Juggling all these activities in your head is impossible, and can become stressful if you are not well organized on paper… not on your computer or cell phone. And now you are going to add to your busy schedule a time-consuming project. It is imperative that you remember to keep these appointments and be on time. I highly recommend that you purchase a Day-Timer, especially when you are doing your science fair project.

> True Story: I taught my son to use a Day-Timer in high school. When he was in law school and took out his Day-Timer® at the end of a job interview, the interviewer asked, “How long have you been using a Day-Timer®?” After a discussion about each of their use of a Day-Timer, the interviewer said to my son, “You’re hired. Anyone who keeps a Day-Timer is someone I can count on!”

I recommend the Day-Timer® 2-Page-Per-Day Indexed Pocket Size Planner. It has room for notes, scheduled appointments and events according to the time of day.

Shopping List 1 Outcomes Checklist

Print, fill out the checklist, attach to your Design Notebook, and date your entry.

Did you accomplish your outcomes today? What’s that? Your Timeline and Day-Timer of course! This is *so-o-o* important. It will make a huge difference when you write your Project Report and Abstract. You will be thanking yourself because the task will go much faster than if you didn’t.

Please be sure you mark ALL the steps and their respective dates on the timeline.

Check off the outcomes you accomplished.	✓
I printed and set up my Timeline.	
I purchased a Design Notebook.	
I set up my Design Notebook so it is ready to be used.	
I purchased my DayTimer and read how to use it.	
I purchased my note cards.	

After you check off all 5 of the outcomes, you are ready for the next section.

Ready to discover among the many topics the one that’s just right for you, read what we are going to do tomorrow? Then close the book and relax. See you tomorrow.

How Science Fair Judges Think

Tips for Doing a Science Fair Project

It is empowering to know what to expect from the Judges. Each school has their own criteria for judging, but here are some factors that judges most often look for when evaluating your project. Get Inside the Judges Mind.

1. **What do you do to ACE the interview?**

Judges walk from display to display, stopping at each one. Some briefly talk to every student and others take the time to do an in-depth interview. Don't panic, it only takes a couple of minutes.

Now is your opportunity to "show your stuff". You can use your display board as a prop, but the Judge wants to hear from you. Don't read from the display board. Use it to highlight your presentation by pointing to the charts, graphs and photos.

- If English is a second language, then take your time in expressing yourself.
- Whatever your native language, talk in an easy, slow pace.
- Clearly articulate your thoughts when you talk with the Judges. Do not mumble. Be confident.

2. **Be Prepared**
   When you have completed doing your science fair Project Report and Abstract, you must get prepared for your interview with the Judges. Being prepared will give you a winning edge.

   - Write a brief two to five-minute talk summarizing your project. Talk about the theory behind it and why your project turned out the way it did. Your Abstract will summarize your project. Be sure to include the following:

     - How you came up with the idea. What problem you wanted to solve.

     - A brief overview of the process you followed. Explain any terminology.

     - Your results and conclusion.

     - How your project contributes to others. Even it will help a small population, your project is important.

     - The Judge will interrupt you to ask questions. You will not be able to tell them everything you know. But being prepared is what is most important.

     - On a 3”x5” note card, write some keywords to help you to remember what you want to tell the Judge(s). Bring this note card to the science fair. You will use it when you talk to the Judge who reviews your project.

   - After you read Questions asked at the San Diego Science & Engineering Science Fair, select a few questions that you think the Judges will ask you. Write the list of questions with their respective answers. Memorize the answers.

   - Read and reread your background research. Memorize the facts as if you were studying for a school test.

- Practice your little "speech" and answers to your list of questions so you know them like you already know 2 + 2 = 4.

    - Practice telling others about your project as if they were the Judges: mom, dad, brother, sister, other family members, neighbor, friends, your pet.

      It is helpful to videotape yourself when you practice. Watch it so you can give yourself feedback. Keep in mind that when you are looking at the feedback it helps you to improve.

      SECRET FILES #4

      If you get upset about what you see, just say to yourself,
      I live in my actions, not my emotions.

    - Be able to explain your tables and your theory behind your data. Use your display board to point out diagrams and graphs.

    - Make your explanation very simple so if a person does not know a thing about your project, they would understand what you say.

3. **Does your display board grab the Judges attention from 3 feet away?**
   The first thing the Judge sees is your display. It does not have to be flashy, but well organized.

4. **When the judge opens your notebook will it be well organized**?
    - Does it have all the basic elements?
        - Daily notes and designs
        - Abstract
        - Research paper with bibliography, problem statement, design sketches, procedures, results - tables, figures and graphs

5. **Were you creative when doing your science fair project?**
    - Does your Problem Statement show creativity and originality?

- Did you go about solving the problem in an original way? Did you give an analysis of the data for the testing of your prototype? An interpretation of the data?

- How about the type of equipment you used? Did you construct or design new equipment?

6. **Did you follow all 8-steps of the Engineering Design Process?**
   - Did you clearly state your problem?

   - Did you use scientific literature or only popular literature (newspapers, magazines, etc.), when doing your initial research?

   - Does your data support your conclusions?

   - Do you recognize the limitations of the testing / data? And did you state them in your conclusions?

7. **Were you thorough in doing your science project?**
   - Did you carefully think out your science fair project, go about it systematically with well thought-out research following the engineering design process and observations?

   - Did you keep a Design Notebook?

   - Did you keep detailed and accurate notes in the Notebook?

8. **What was the quality of your technical skill?**
   - Did you have the required equipment to obtain your data?

   - Was the project performed at home, school, university laboratory?

   - Where did the equipment come from? Did you build it? Did you loan it from somewhere? Did you work in a professional laboratory?

   - Did you do the project yourself or did you receive help? If you received help the Judges are looking for you to give credit to those individuals.

9. **Did you have clarity with the details of your science project?**
   - Sometimes you may be asked to explain a short version of your project. This is where your abstract will be helpful. Look it over and become familiar with the information.
   - Are you familiar enough with the material to answer questions? Judges are not interested in memorized speeches or trivial details. They want to know what you learned.
   - Can you explain the purpose, procedure, and conclusions of your project?
   - Does your written material, including your abstract, tables, charts and graphs, show that you understand your research project?
   - Is your material presented in an orderly manner?
   - Is the data of your project clearly stated?
   - Are the results of your project clearly stated?
   - Does your project display explain your science project?

10. **What are some questions that you may be asked?**
    Helpful Hints
   - What is most important when answering the Judge's questions is to be honest. If you don't know the answer, then be truthful.
   - Judges like spontaneous answers. Don't try to memorize answers. Know your stuff cold like you know 3 + 3 = 6. And you do, because you did the work! (Remember that computer brain of yours?)
   - Know the formulas, terms and acronyms that you used. They may ask you to define some of the scientific jargon that you used.

- Science Fair Judges want you to succeed. They want you to shine. They are not trying to stump you or get you flustered.

- Either during your presentation or afterwards, the Judge will take notes. Don't panic! Many have to fill out a form for each project that they see. On that form are 5 areas (creativity or engineering ability, thoroughness, skill and clarity).

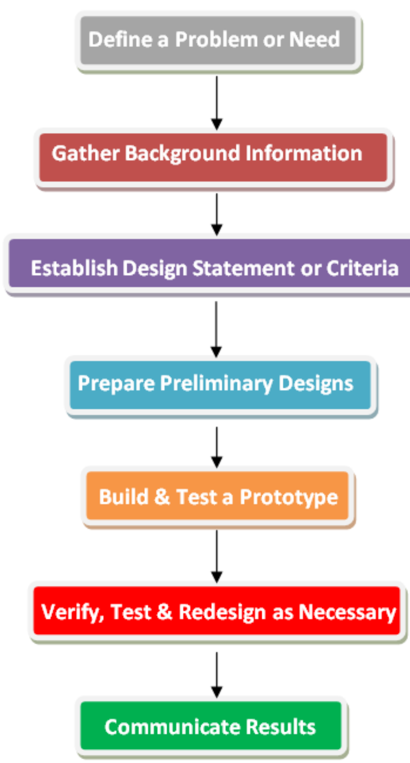
11. Glance over the Judges Score Sheet and The Judges Engineering Design Interview.

The Engineering Design Process vs The Scientific Method

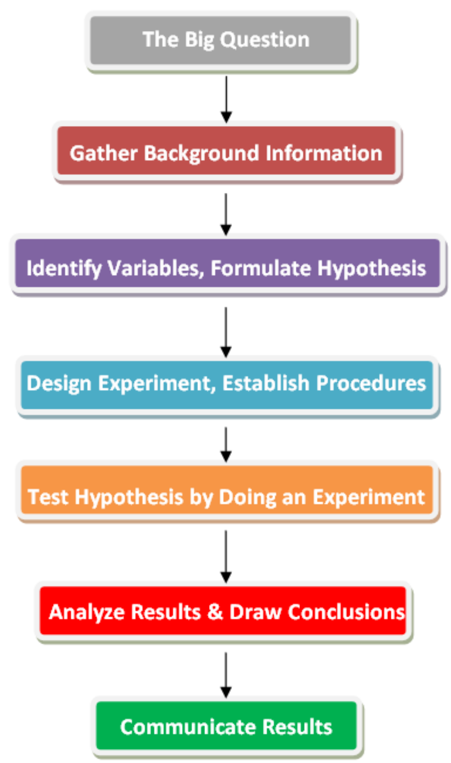
The Engineering Method – Engineers invent things that never existed before. They identify a problem and then follow the steps of a process that leads them to a possible solution. If the prototype does not work then they go back and refine, retest the prototype and / or brainstorm solutions, re-evaluate, and choose a different solution.

The Scientific Method – Scientists study things in the natural world to see how they work. They make observations about what they see, create hypotheses, and then design experiments that will either prove or refute them. For a science fair project, you need to do 3 to 5 tests to get what is called a “fair test”.

THE ENGINEERING DESIGN PROCESS



THE SCIENTIFIC METHOD



In either case, the designer /experimenter will find himself or herself going back and forth between steps. Working in this manner is called “iteration,” and it is especially common during the final steps of the process.

ENGINEERING DESIGN PROCESS

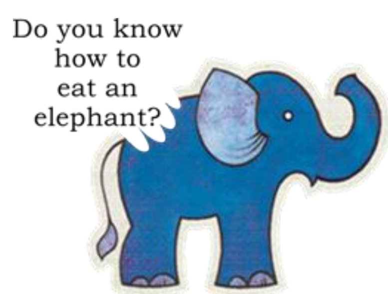
Letter "AE" on the Timeline

Background Information

"The crux of the design process is creating a satisfactory solution to a need. The need may be to improve an existing situation or to eliminate a problem. In any case, it is what engineering is all about—using knowledge and know-how to achieve a desired outcome."
Lee Harrisberger, Engineersmanship… The Doing of Engineering Design

Engineering is the application of science, mathematics and experience to produce a thing or a process that is useful. Engineering is neither more nor less important than science, just different. The basic objective of engineering is to use scientific principles and methods to produce useful devices and services that serve mankind.

Keep this in mind, no one really knows how many times Thomas Edison tried to make a light bulb…somewhere between 100 to 1000 times. Failure wasn't failure to him; failure was one step closer to finding a solution.



Bite by Bite!

Thomas Edison was an inventor. He was looking for a specific outcome. He wanted to make a light bulb that would last for hours. Do you see the difference? What Edison did is termed an Engineering Design Process.

Q. How does the engineering design process differ from the scientific method?
A. Engineers create something new, whereas scientists study nature and how it works.

Q. What is the engineering design process?
A. It is a series of steps that lead you from finding a problem or need and designing a solution.

Q. What is the first step of the engineering design process?
A. Defining the problem or need.

Q. What is the next step?
A. Do some research around the subject. – Do Background Research

Q. What is the third step?
A. Based on your research and observations, write a design statement or criteria.

Q. What is the fourth step to designing a solution?
A. Draw a preliminary design – this is the fun part.

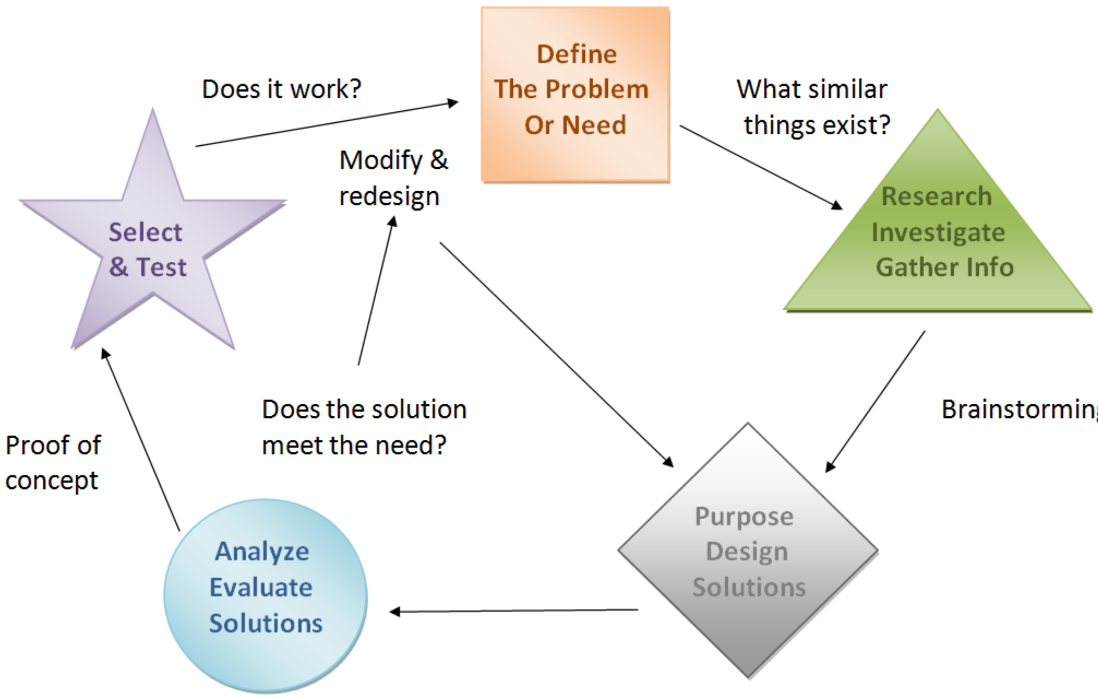
Q. What is the next step?
A. Build and test your prototype.

Q. What is the next step?
A. Go through all your data, analyze it, test and redesign if necessary.

Q. And the final step is…?
A. You must communicate the results.

Notice in the diagram below that the Engineering Design Process is really not a step-by-step process. Oftentimes an inventor needs to fine tune the design or start over with a new design. S/he goes back to repeat steps until the invention works and fulfills the need. Remember, a process that involves "backing up" is called an **iterative process**.

THE ENGINEERING DESIGN PROCESS



Overview

Before we begin, let's make this perfectly clear. Doing an engineering science fair project may be overwhelming, frustrating and daunting, especially when you go through the retesting and refining process. BUT your results will be worth all the effort. Please keep in mind, a purchased kit cannot be used for an engineering project. Raw materials found around the house or purchased at a store are used.

Ready for an adventure? If your answer is "yes", let's go….

Bet you have used a telephone and enjoyed the benefits of using air conditioning. Do you know who made those things possible? Engineers. They design and solve things to solve problems. It is a **design and construction** of an **engineered product** for **target users** to **do some useful function**.

If you are going to do a project that involves programming, inventing or designing or modifying a device, a computer program, algorithm or procedure, then you are going to be doing an engineering science fair project.

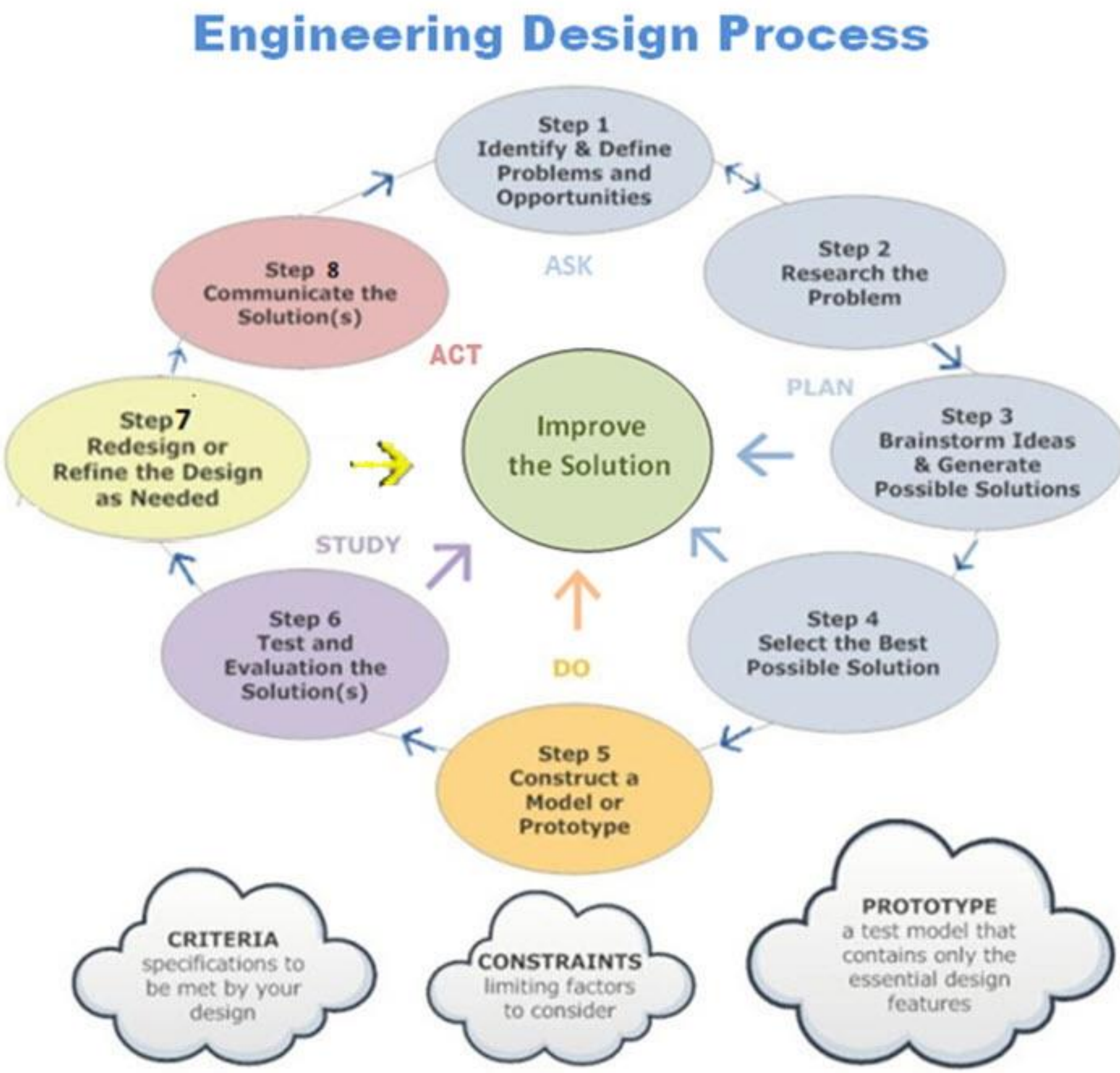
Engineers participate in designing, creating or revising nearly everything we touch, wear, eat, see and hear. An engineering science fair project connects real-world experiences with your daily life.

Here is an excellent explanation of what engineers do. You will be amazed at the many facets of engineering: http://www.egr.msu.edu/future-engineer/what

Detailed Steps of the Engineering Design Process

All engineers, individually or as a team, follow a series of steps to solve a problem. While engineering projects are part of science fairs, the engineering science fair design is different. The process is called, **Engineering Design Process**.

The steps are cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way. It is also called a dynamic process, not stagnant. That means that the process does not move in a linear fashion, you may go back and forth between the steps.



1. Identify and Define Need or Opportunities
2. Research the Problem – Do Background Research
3. Brainstorm Ideas and Generate Possible Solutions
4. Select the Best Most Promising Possible Solution
5. Construct a Model or Prototype
6. Test and Evaluate the Prototype (Solution)
7. Redesign or Refine the Design as Needed
8. Communicate the Results

The key themes of the engineering design process are **teamwork** and **design**. When you keep in mind **open-ended design**, creativity and practicality, you will strengthen your understanding of this process.

The goal of your engineering project is to design and construct a prototype for someone to use to perform a useful function.

Examples:
"The goal of this project is to design, build and test a way to minimize waiting time at stop lights in the city during rush traffic between the hours of 7 AM to 9 AM and 4 PM to 7 PM."

"The goal of this project is to design a computer program that will send orders automatically from a shopping cart to a warehouse."

Step 1. Identify the Need

Find a Problem

Letter "AC" on the Timeline

Generate Engineering Project Ideas

Before solving a problem, you need to **identify and define the problem** you want to solve. Find a problem that you or someone you know has experienced. Problems and needs are everywhere. To find an idea for your engineering project requires only that you open your eyes and really look around.

As you gather ideas that interest you, make a list in your Design Notebook.

- Ask yourself some questions: What bugs me? What bugs my friends and neighbors, my family? What is needed that will make my life easier? Make my family and friends life easier?

  Go into your local stores and ask each owner what kind of problem s/he would like to solve. It may be a product or a functional requirement (a more effective way to get heavy merchandise from the warehouse to the store). Keeping the problem local increases the likelihood that it will be a manageable project.

  There are two types of "bug" lists you can make.

1. An unsolved problem – one that has not been solved yet.

   Example: Flow of traffic during peak travel times. There has to be a more efficient way to build a roadway or traffic light algorithm where people are not stuck for hours in traffic in the morning and evening.

2. A poorly solved problem – one that has been solved but you believe that could work better with an improved design. Look around and see what things exist that could be improved. You don't want to duplicate something that already exists. For instance, you may find a more environmentally friendly way to make a product using recycled material.

   Examples
   Kitchen sinks come with a drain filter, but none of them really stop the very small food particles from going down the drain. Eventually the drain gets clogged from the accumulated particles.

   Another good example came from the man who helps us to blow stuff up. Alfred Nobel was the person who invented dynamite and was the person that the Nobel Peace Prize was named after. He saw a need because miners and other people needed explosives in their jobs. Before Nobel invented dynamite, he did research to see what other explosives existed, which ones worked well and which ones didn't.

Informal Survey

Take an informal survey of your family, friends and teachers. Explain to them that you are investigating ideas for an engineering science fair project. Ask them what bugs them, what is a problem that they would like to solve in regards to how to make their life easier.

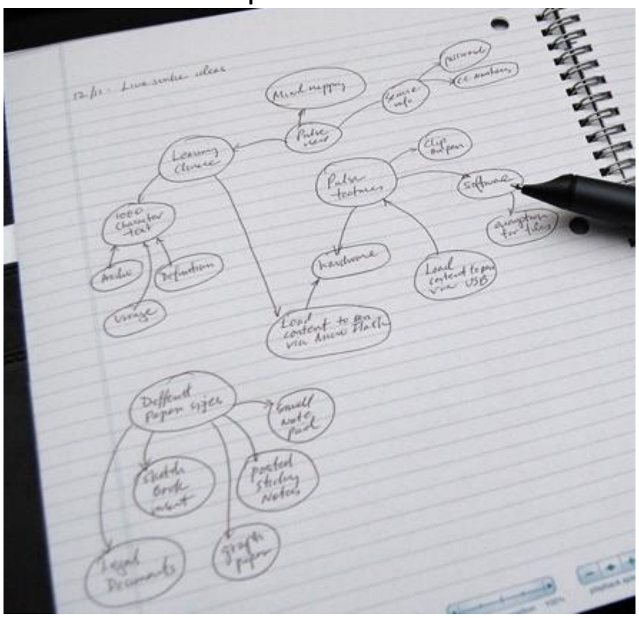
Mind Mapping

Mind mapping is a visual process that creative people use to express and generate ideas. It is a tool that allows you to be creative without judgment and allows for a free-flow of ideas.

Begin in the center of the page with a circle. Within that circle write the main idea. This could be the problem you want to solve, the product you want to improve, or just an idea that you have. You can use words or drawings to express your thoughts. Everything will stem from this central idea.

If you are doing an advance project (high school or college) you may want to look at this free mind mapping program. http://www.thebrain.com/#-55

Here is a typical layout of a mind map.



Remember, your project must be original, but the following website can help you to look at what others have done. You can use these ideas as a springboard. Keep in mind bigger, cheaper, faster, lighter.

https://abstracts.societyforscience.org/
http://www.howstuffworks.com/
http://amasci.com/search.html - use their search engine – input the word, engineering

- Do an Internet search using these keywords: unsolved engineering problems.

- Look in the Appendix of this book:
  50 Engineering Science Fair Project Ideas
  Science Fair Topics to Avoid

Write the Problem Statement

Letter "AB" on the Timeline

Now that you have found a problem it is time to describe the problem by writing a **problem statement**. It tells what the program is, who has the problem and why it must be solved. It is often stated as bigger, cheaper, faster or lighter. The problem statement answers all three of the following questions.

- What is the problem or need? (need)
- Who has the problem or need? (user)
- Why is it important to solve? (insight)

Here are some other critical questions that Engineers ask themselves about what they want to create, whether it is an amusement park ride, Smartphone, computer tablet or bicycle.

- What do we want to design?
- What do we want to accomplish?
- What are the project requirements?
- What are the limitations?
- What is our goal?

The **Problem Statement** is written simply, and in a specific format and must have technical content. **Write your Problem Statement now**.

Example:
Who need(s) what because why
Who need(s) ________ because ________?

Alexander Graham Bell wanted to come up with an easier, cheaper way to communicate. At that time the best he could come up with was a telegraph, which was a way to send messages over electrical wire.

Bell identified his problem: communicate with people who were **far away** without it **taking a lot of time** and being **expensive**. He came up with the telephone.

Problem Statement Outcomes Checklist

Print, fill out the checklist, attach to your Design Notebook, and date your entry.

Check off the outcomes you accomplished.	✓
I brainstormed ideas and chose an engineering problem to solve.	
I wrote my problem statement according to the suggested format. Write your Problem Statement here:	
My problem meets my teacher's requirements.	
My topic will keep me interested for the next 2 to 3 months.	
I believe I can find at least 3 resources on the subject.	
I believe there is a way to measure numerically (cheaper, faster in time) how my solution will be better than what exists.	
The solution I have in mind will be safe to build, use, store and dispose of.	
Check 1 or both. ◦ I have all the materials to build the design I have in mind. ◦ I have access to obtain the materials at a low cost.	
I have enough time to build / design my solution by the date the project is due. Keep in mind that many times you have to redesign or refine the solution and then start all over again to test it and do a data analysis.	
I do plan on entering our school's science fair contest and checked to see if I need permission to build the design. (Explain what you found out.)	

1st Meeting - Get Teacher & Parent(s) Approval

Letter "AA" on the Timeline

It is important to get approval for your solution from both your teacher and parent(s) because there is no sense in doing Background Research (which takes a lot of time) unless everyone is on board. You are probably very excited to get started but remember that your teacher has rules she has to follow and your parent(s) have to pay for the materials and supplies.

An engineering science fair project takes a tremendous amount of time and effort and you will need the support of both your teacher and parent(s). May as well have a cooperative attitude rather than bucking the system.

Remember to be enthusiastic, positive and honest.

Bring your Problem Statement and the answers to the Critical Questions with you when meeting with your teacher. Ask her/him to give approval of the project.

Explain that you will ask to have another meeting with her/him after you do your background research, developed a few possible solutions, chosen the best solution and written your design requirements and design brief.

Once your teacher approves the idea of your project, have a meeting with your parent(s) and get their approval. After all, they will have to financially support your project. Keep in mind that they have a household budget they have to adhere to.

Step 2. Research the Problem

Purpose of Background Research

Once you decide what the problem is that you want to tackle, you need to do your background research in order to know what has previously been done and what others found out. This will help you to find excellent alternatives for cheapest, fastest, or lightest criteria and to come up with alternatives that meet the design criteria and constraints.

Background Research will help you to

- formulate questions about who your **target users** would be.

- formulate questions about existing products that might solve either the problem you identified or a similar one.

- research how your product will work and how to make it work.

- get suggestions about where to find resources and materials that assist you better in understanding your project. The more specific questions you ask, the more helpful the responses will be.

What you will Research

- What has been done to satisfy similar needs?
- What knowledge and science limitations will limit your solutions?
- What previous solutions may be improved?
- What different approaches may meet your design objective?

In other words, find out what others already know and did! First use primary sources such as talking with local experts and draw from your own experiences. Then research secondary sources such as magazines, books, articles, textbooks or Internet sites. At least 3 research sources must be used.

Different Types of Scientific Investigations

SECRET FILES #5

Before you begin your background research, it is important to know the various types of investigation.

1. **ENGINEERING DESIGN PROCESS**
   Design and Construct an engineered product for target users to do some useful function. Examples: robot, device, program for a computer. You are not allowed to use a kit for this. The project must be original.

2. **INVESTIGATIVE**
   This is a project that asks a question, constructs a hypothesis, draws a conclusion and then tests that hypothesis by constructing an experiment using the scientific method.

3. **LABORATORY DEMONSTRATION**
   This is a project that repeats an "experiment" found in science activity books, textbooks, workbooks and encyclopedias. No unique questions are explored.

4. **REPORT AND POSTER**
   This is a project based on extensive research done in books and other materials in order to write a paper on the chosen topic. Posters (display boards) are then used to illustrate key concepts from the research paper.

5. **HOBBY or SHOW-AND-TELL**
   This is a project that consists of either a collection of objects or features interesting artifacts. Involves library research but no hypothesis is tested.

6. **MODEL BUILDING**
   This is a project which involves the construction of a model that may illustrate a scientific principle.

What kind of project is of interest to you? What will keep you focused and enthusiastic for 1 to 3 months? Before you decide, ask your teacher if a particular kind of project is required for your science fair. Most regional and state fairs require the Investigative or the Engineering Design Process type of project.

Three Types of Background Research that Engineers Use

1. **Observation** – observe users in the environment where the problem exists or while a similar product is being used.

2. **Examination and Analysis** – examine and analyze similar products and solutions. Ask if you can take them apart. You will learn from other's experiences.

3. **Library and Internet Research** – Click on the links for more details.

Overview

Nowadays, there is a huge amount of information available on any given subject. That is why you must make a background research plan for your science fair project. The plan will give you a reliable roadmap to help you find your way from questions to answers without taking unnecessary detours.

Your research will lead you to techniques and equipment others have used in similar projects. This information is helpful for when you do your project and write your Project Report. If there are mathematical equations that help to explain aspects of your project, you will include them too.

Smart investigators use the library and Internet to research the best way to do their project. You will need at least 3 resources as references. Intel ISEF requires "5 major references – science journal articles, books, Internet sites."

Some teachers require original research. Read further to find out about original research.

- Before you begin your research, you are must learn how to organize and keep track of references that will eventually become your **Bibliography**.

- Within the Bibliography section is information on how to use **note cards**, which you also will need to do. Read in more detail how to write and organize your note cards. They are an important part of your project research and will be needed when you write your project research paper.

Bibliography

Overview
After you develop the background research plan, you're ready to gather information from reference and text books, from newspaper, journal and magazine articles, from websites, and from wherever else your search takes you.

The Bibliography is a carefully organized list of bibliographic information (references) for each source that you have cited in your paper. These are required standards for research papers to follow when you document your sources. All of them contain the author's name; title of the book, magazine or journal; the date the material was published; and the source - who published the information.

In your report you will give credit to all the authors whose information you used by citing their names and the dates of their publications. That way, anyone reading your report will be able to go to the bibliography for more details.

Background information resources give general information about a variety of topics. These are considered to be general reference sources, meaning that they provide facts and knowledge that can be used as a foundation for your research. You only need to spend a little time using these resources but they will save you a tremendous amount of time when searching in databases and more subject-specific resources.

Almanacs
Bibliographies
Biographical resources
Dictionaries
Directories
Encyclopedias
Handbooks
Statistical sources
Thesauruses

Details
There are two ways to record and keep track of your references: 1). bibliography worksheet and 2). Index cards

1. **Bibliography Worksheet**
    - Take out the 4 printed copies of the Bibliography Worksheet.

      Keep a list of all the books, articles and websites you search through as you gather information for your science fair project in your Design Notebook or on note cards.

      You will need **three to five written sources at a minimum** to create the bibliography, which will become part of your final report.

      For each printed source write down
      (book; encyclopedia, newspaper, original research paper, or magazine, article)

    - The author's full name, putting the last name first
    - The title of the book or article and the date it was published
    - For books, the publisher's name and the city and state where it is located
    - For articles, the volume number of the magazine or encyclopedia; also, the page numbers

      Printed sources put most of this information up front, on a title page or in the editorial "masthead".

    For each website write the following information:

    - The author's full name, if it is listed
    - The page title
    - The name of the company that posted the page
    - The web address (URL) for the page
    - The date you last looked at the page

You'll find most of this information in a website's "about" or "contact" page, or at the page's header or footer.

List all of your sources alphabetically. In cases where you don't have an author's name, write down the title and insert it into the list, keeping the alphabetical order.

Cut the sections of the Bibliography Worksheet that you used and tape or staple them into your Design Notebook when complete. Date the entry.

Examples

There are various types of bibliography formats. U.S. schools usually ask their students to use the MLA (Modern Language Association) and the APA (American Psychological Association). The MLA calls the bibliography, *Works Cited*. The APA use the term, *The Reference List*

- MLA - English and humanities instructors ask you to document your sources with the MLA system of citations.

- APA - Many social science instructors ask you to document your sources with the APA system of in-text citations and references.

- CSE (Council of Science Editors) is used by many science teachers.

Some people use a mixture of all three types of listings:

- APA to format for online sources
- MLA to format all other sources
- CSE to format citations from articles

Ask your teacher which format to follow.

Dixie State University Library shows you how to format each type of bibliography style. http://libguides.dixie.edu/c.php?g=57887&p=371717

Bibliography Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry. You will be using it after you do your background research.

Remember, a good bibliography requires that you have at least 3 to 5 primary sources of written information in addition to web pages you have consulted.

Bibliography	✓
I have 3 primary references on my science fair topic.	
All my references include the information required by APA, CSE or MLA writing style.	
All my references include required information: author's name, title of the book or article, date and place of publication.	
All my references are listed in alphabetical order, starting with last name, then first name. (You will need to do this when you type your Project Report.)	
I have at least one reference for each of my research questions.	
I taped / stapled the Background Project Research Worksheet in the Design Notebook and dated the entry.	
I taped / stapled the Big Question Worksheet in the Design Notebook and dated the entry.	
I taped / stapled the Bibliography Worksheet in the Design Notebook and dated the entry.	

Do not go onto the next page until you checked off every single item in the above checklist. I know it is a lot of work, but you will be thrilled when you use the information to create your invention or computer program.

How to Write Note Cards

You are going to need a system to organize the information you find when doing your research. Having a system of taking notes will make it easier to do this. A recommended method is to use note cards / index cards.

An easy way of collecting your references and keeping them in order is to use 4" x 6" or 3” x 5” note cards. To keep them organized, use a rubber band to secure them. When you are ready to write your Bibliography, it is easy to put them in alphabetical order. Place them in a safe place.

You are going to have two different kinds of cards, source cards and information cards.

Source Note Cards

Use the **<u>white cards</u>** to track where you found each piece of information. Number the cards for each source. If you need to use more than one card per source then number them this way: Source 1-A, Source 1-B.

- In the upper left corner write the keyword phrase or subject.

- In the upper right corner write the number of the source.

This is what it will look like:

science fair projects	No. 1
Binder, Madeline, M.S. Ed, M.S. Human Services Counseling 2017 Student’s Guide to Science Fair Projects, Step-by-Step for a Winning Edge Evanston, IL M-ZAN Solutions, Inc (publisher) (eBook)	

Here are examples of information you will need to write on your bibliography source note cards:

- **Books**
  Name of book, author, publisher, copyright date, pages read or quoted.

- **Journals and Science Magazines**
  Name, volume, number and date of publication, title of article, author and pages read or quoted.

- **Newspapers**
  Name, date, section and pages of newspaper, author, title of article.

- **Encyclopedia**
  Name, volume, number, publisher, copyright date, title, author, pages of article.

- **Science Fair Software Packages**
  Name of program, version or release number, name of supplier, and place where supplier is located.

- **Documents online**
  Title, author and date of article, organization that posted the document, organization's location and online address.

Information Note Cards

The 2nd set of cards is called information note cards. Use **<u>different color cards</u>**: one color for each keyword phrase or keyword question.

They will be used to collect the information that answers your keyword questions (explained in detail later on in this book). The information gathered will be used to refine your testing procedure and write your Research Report.

Always keep in mind the purpose of your research paper: it is to give information so you have an understanding of other similar designs plus successes and failures of other inventors' solutions. It also gives credit to authors whose work you've consulted in your research. This makes it easy for a reader to find out about your topic by examining the research that you used to write your paper.

List the key points and quotes, and put the name of the source at the top of the card. Each card will be from one source that answers a keyword question. You may have more than one source per question.

If you prefer to type notes directly into an electronic device, be sure to keep track of your sources. Use a different color card for each keyword phrase. The following image shows you what the card will look like:

Keyword / Keyword Phrase	Source #
Keyword Question	
Quote or notes you put into your own word from the reference.	
	Author's Last Name / Page(s)

Here is an example:

free wind blade turbine	# 1
Who invented the free wind blade turbine?	
Chris Gabrys and Tim Rodgers, and Mike Hess, a successful entrepreneur	
and former CEO, Windspire Energy	
This came from an email response 9/5/16	
	Email from owner of Windspire: Richard Kline

- In the upper right corner of each card write the Number of the card. This number will correspond to the number of the source on the **Bibliography Worksheet** printable or note card that you use to document your references.

  Number the cards for each source. If you need to use more than one card per source: Example – Source 1-A, Source 1-B

- In the upper left corner of the card write the keyword phrase or subject.

- In the lower right corner write the author's last name and the pages where you found the information.

- Write a single thought on each card that paraphrases the text. If you want to write a direct quote, make sure that you place parentheses around the quote. That way you give proper credit in your paper.

Note Taking Tips

- **Paraphrasing vs. Plagiarism**

  Paraphrasing is writing something in your own words. It means that you completely restate the complete thought. Replacing a couple of words is not good enough; you need to make what you write your own.

  Plagiarism is copying another person's words as if they were your own. This is true whether the source is a book, journal, reference book or from the Internet. This is like stealing something from someone else. Be sure to put quotes around something that you copy.

- **What to include in your research paper**
  - History of similar experiments or inventions.
  - Definition of all-important words, terminology and concepts relevant to your experiment.
  - Answers to all your background research questions.
  - Mathematical formulas (if any) that you will need to show the results of your experiment.

- **Quoting Text**

  If you are using the author's own words, phrase, sentence or paragraph, you must put them in quotation marks.

  Example:
  "All life is an experiment. The more experiments you make the better."
  (Emerson – 1860)

- **Citations**

  In writing your research paper, it's okay to copy pictures, diagrams or ideas from one of your sources – as long as you give credit to the author or source.

You do this with a citation using the author's name and publication date (Jones, 2010) at the end of the sentence but before the period.

Document all facts, pictures, diagrams, illustrations, charts and graphs. Write the author's name and date of each publication immediately following the reference. This is called a reference citation (APA format) or parenthetical reference (MLA format).

Creating a Background Research Plan

Details for Keyword Worksheet

Letter "Y" on the Timeline

Use the **Keyword Worksheet** pintable that you printed for this section. Follow the instructions on the sheet as you read the information and directions below.

Step 1 – Determine Your Keywords

Research the Who, What, Where, Why, When and How

You'll find the keywords for you experiment in your project question, but also brainstorm for additional keywords and other concepts you want to explore.

When you search for your keyword phrase, look at the bottom of the search engines' pages, you will see more suggested keyword phrases. You can also delete some words from each keyword phrase to simplify your search.

Here are some free keyword search resources for you. Before you register, if you are under the age of 18, check with your parents to see if it is OK to sign up: Wordtracker Free Keywords Search and Bing Keyword Toolbox

Date this entry and tape or staple the Background Project Research Worksheet into your Design Notebook.

The Details for Question Word Worksheet

Letter "Y" on the Timeline

Step 2 – Write Questions Pertaining to the Keywords

The following information gives you a plan of action. The Question Word Worksheet is an excellent way to generate ideas for your background research.

Take out the **Question Word Worksheet** that you printed.

The secret to using the worksheet is to write questions for each of your keywords and then decide the ones that are relevant to your topic. Fill in the blanks for each question pertaining to your subject.

- You will be using what, when, where, how, does, why, and which to help you transform your keywords into more specific research questions. Come up with as many keywords and questions as you can, then go back later to eliminate any that are not relevant to your project.

  Examples of Questions:
  What is the difference between a propeller vertical wind turbine and a propeller free wind turbine?
  When are hydro wind turbines used?
  What makes one paper towel stronger / more absorbent than others?
  How does a solar panel work?
  Does sun energy produce more power than wind energy?

  The questions are examples to help you get started with your keyword search. Develop your own questions related to your project.

- You may find a lot of interesting questions to research, but they do not have anything to do with your experiment. These are called **irrelevant questions**. Later you will have to eliminate those questions that do not really have much to do with your solution and would, therefore, not be helpful to answer.

Be aware that a question might seem irrelevant on the surface but may be worth exploring at some future point. In that case, set it aside and come back to it later when you can look at it with fresh eyes.

For example, it might be interesting to know about the history of wind turbines, but not necessarily important to designing more efficient vertical wind turbine blades.

Example of a Keyword Question Chart

When I did a search for *quiet wind turbine experimental kit* or *propeller free vertical wind turbine experiment kit*, nothing came up. I used the term, *wind turbine experiment kit* and *propeller free turbine*.

Propeller Wind Turbines vs Propeller Free Wind Turbines

Questions	Keywords to Search	Possible Questions to do Background Research	Is the Question Relevant
Who	Propeller free vertical wind turbine	Who needs use a propeller free vertical wind turbine experiment kit? Who invented propeller free vertical wind turbine?	Yes, students who want to learn about a more ecological wind turbine No. Mariah Power original manufacturer. Inspired by a windmill that Egyptians used to grind wheat over 3,000 yrs. ago.
What		What is the difference between a vertical wind turbine with traditional blades and the propeller free turbine? What properties are contained in propeller free wind turbine that makes it more environmentally friendly and energy efficient?)	Yes, for both questions
When		When would a company / person use the propeller free turbine? When did people become interested in the propeller free turbine?	Yes No
Where		Where is the propeller free turbine being used now?	Yes
Why		Why was the propeller free turbine designed? Why do people who own homes and companies use wind turbines?	Yes, to both questions.
How		How will students benefit from experimenting with the propeller wind turbine?	Yes, learn about the product and you can improve upon a product.

After you have completed using the Question Word Worksheet, tape or staple it into your Design Notebook. Remember to date the entry and any brief notes you need to add.

Networking is an important process to learn when doing research.

- **Ask questions of people from various backgrounds and specialties** to assist with researching what products or solutions already exist, or what technologies might be adaptable to your needs. Ask your teacher, mentor, parents, students who have completed an engineering science project.

- **Interview experts in your field of interest**. They have a wealth of information they can impart to you.

- Talk with other students who have completed science fair projects.

Research Target User or Consumer

Letter "X" on the Timeline

Once you interview experts and have a better understanding of the product you want to develop, interview your target user or consumer. Be sensitive to their needs such as not using small parts when developing a product for a toddler or the end cost to the consumer. Collect the following data.

- Age
- Gender
- Occupation
- Hobby interests
- Amateur or professional
- Special needs or accommodations
- Size
- Experienced or 1st time user
- Legal requirements

    - Identify questions to ask about products that already exist to solve the problem you defined or a problem that is very similar. After all, you don't want to do a project and then find out it already exists! Or when considering new technology and environmental needs, you may come across a product that can greatly be improved and serve the end user or customer.

    - Research will also help you to find out how to make your product and how it will possibly work. Background research will help you to discover materials you can use to build a prototype and the science behind the materials used. If you are going to enter a science fair the Judges will want to know that you have these understandings.

- If you are not sure whether or not a question is relevant then ask the opinion of others who may know more about your subject, such as parents, teachers and mentors. If you cannot find out about the relevancy of a question, don't worry about it. The answer will come apparent when you design your solution/product.

- Questions to ask to refine **your target user's needs**:
  - Who wants this product or solution?
  - Who needs this product or solution?
  - Who would buy this product now?
  - What does my user need and want in my product or solution?
  - What is the best size to make my product?
  - How much is my target user spending now for a similar product and how much would they be willing to spend for mine?

- Questions to ask about a **competitor's similar product:** One way to identify the characteristics that are needed is by examining a similar product that is already in existence. Whether it's a tangible item, a piece of technology, a product that exists in cyberspace, some feature of the workplace or school environment, or an issue related to a personal experience, you'll want to note key features of your design and how they work to create a solution.

  - Who invented the product?
  - How does it work?
  - What parts make up the product?
  - What are the characteristics that make the product user friendly and viable in the market place?
  - Where is the product used?
  - What need does it fill? You must know what needs to be met for your design to be a true solution. A successful design contains those characteristics that enable it to solve the problem.
  - What materials are used to make the product?
  - What do I believe is the best material, component or algorithm for building a similar product?
  - Research how your product will work and how to make it.

How to Interview Experts in Your Field

The experience of others is part of a background research plan and also part of not “reinventing the wheel”. This is called “networking”. The people you want to interview are usually experts in their field, have taken some classes on the subject, or have done an engineering design project similar to yours: engineers, professors at engineering schools, doctors, lawyers, veterinarians, researchers, science teacher, friends’ parents, and authors of the articles you read. Local research firms will have experts who may also help you. You may interview the expert in person or over the Internet.

Don’t be intimidated when it comes to networking. Everyone does it. You have even experienced networking when you were deciding what kind of cell phone you wanted. You probably talked with various friends and family members to find out what phone they enjoyed using the most. Become an expert networker and you will create a unique and excellent science fair project.

PLEASE do not, I repeat… DO NOT ask anyone for a science fair project. Experts are strictly there to help with giving you information in their field of expertise.

How to Schedule a Meeting with an Expert

Make an appointment with an expert, either by phone, email, Skype, FaceTime or Zoom. Agree to the amount of time to talk. A good rule is to not stay longer than 20 minutes. Ask permission to record the interview. Wear a watch.

- Start on time and stop on time.

- Sincerely thank the person for his / her time and information.

After the interview, listen to the recording. Write in your Design Notebook the person’s name, company, position, expertise, date of interview. Write a thank you send it by the next day.

Ask very specific questions. Solid questions tend to yield good, solid answers that will help move your project to a successful conclusion. Be quick, efficient and smooth. In other words, be prepared.

Example of Questions to Ask an Expert

Choose your questions from your **Question Worksheet**. Use it as a guide. Write your questions in advance and bring them with you to the meeting. Remember, you only have 10 to 20 minutes, so choose the questions that are most relevant to your project research.

Example: I am planning on designing a kit for students who want to experiment with a quiet wind turbine.

1. What science concepts are best to study to better understand my project?

2. How does a wind turbine with blades differ from a Propeller free vertical wind turbine design in terms of its efficiency? In terms of cost?

3. Are there different types of Propeller free blades?

4. What role does the blade's shape and size play in the efficiency of a wind turbine?

Tips

- Know what you are going to ask before you do.

- Look the person in the eye, shake their hand, but not too hard or too soft, but firm. Practice with each member of your family. Ask for feedback. It is a life skill that is important. Or do an elbow bump… whatever the present protocol is in your country.

- Thank them for meeting with you.

- Ask if they can lead you to resources or more experts.

- When you are finished, ask if you can quote them as a source in your report. Then, on a note card, write their information.

- Shake their hand or do an elbow bump and thank them again.

- Write a thank you note and thank the person for contributing their time and expertise.

How to Find an Expert on the Internet

Do a search in Google, Bing or Firefox. Search for the keyword phrase, *ask a __________expert*.

Examples: *ask a physics expert* or *ask a wind turbine expert*.

Ask an Engineer here https://www.kclengineering.com/ask-an-engineer

Write a Letter of Inquiry

Your complete name
Your street address
Your city, state, zip code

Person's first and last name you are writing to
Name of company (if you are sending the letter to his/her place of work)
Street address
City, State, Zip Code

Month, day, Year

Dear (Mr., Mrs., Ms or Sir):
I am a student at Jones School in the (grade level) and am doing my science fair project on quiet wind turbines. I understand that you are a wind turbine engineering expert.

I would appreciate you answering one or all of the follow questions and sending my relevant information that you would have as soon as possible.

(insert your questions here)

Thank you very much for you time and effort,

(sign your name here)

(Print by hand or input on the computer your name here.)

Show the letter to one of your parents and ask permission to include your telephone number and email address.

Sometimes it helps to enclose a self-addressed, stamped envelope.

If you can contact the person via email, you may receive the information sooner and it is much less expensive and time consuming than snail mail.

Keyword & Question Checklist

Print this page, check off the outcomes on the list, attach to your Design Notebook, and date your entry.

Check off all the outcomes you accomplished.	✓
I have identified all the keywords related to my project and completed the Keyword Worksheet.	
I have completed the Question Word Worksheet for each of my keywords. ◦ I have removed irrelevant questions, but put them aside in case I need them later. ◦ One or more of my research questions specifically asks about the equipment or techniques I may need to make my design.	
I networked and asked if a product I want to design already exists or if there are technologies that might be adaptable to my needs. ◦ I interviewed experts and sent them thank you notes. ◦ I interviewed friends, family and teachers. I am asked if they knew of experts that I could communicate with.	
I have researched my target users, customers and/or consumers ◦ I wrote questions to ask about my target user / consumer's needs. ◦ I found out their characteristics and needs. ◦ I wrote questions to ask my competitors. ◦ I have identified questions to ask about products that already exist that will help to solve the problem.	
I documented all my activities and attached all my worksheets in my Design Notebook.	

When you have completed this section pat yourself on the back for a job well done.

What is Original Research?

Judges will check to see if you used original research. Research that comes from a primary source is considered original research. An article is considered original research if the...

- report of a study is written by the researchers who actually did the study.
- researchers describe their research question and the purpose of the study.
- researchers detail their research methods.
- results of the research are reported.
- researchers interpret their results and discuss possible implications.

How Do You Know if the Article is Original Research?

There is no one way to easily tell if an article is a research article like there is for peer-reviewed articles in the Ulrich's database. The only way to be sure is to read the article to verify that it is written by the researchers and that they have explained all of their findings, in addition to listing their methodologies, results, and any conclusions based on the evidence collected.

However, there are a few key indicators that will help you to quickly decide whether or not your article is based on original research.

- View the PDF version so you can plainly see the major subdivisions that need to be present in a research article:
    - Literature Review or Background
    - Methods
    - Results
    - Conclusions
    - Discussion
- Read through the abstract (summary) before you attempt to find the full-text PDF. The abstract of the article usually contains those subdivision headings where the key sections are summarized individually.

- Ask your librarian to see if s/he has access to scholarly journals and research databases.

Where to Find Original Research

Overview

- The easiest way to begin is by looking up each of your keywords in an encyclopedia or textbook. This will give you general information and help orient you to your subject. Text books and encyclopedias include bibliographies that can be used as sources that can lead you to other sources.

- Specialty magazines target a specific interest report on research projects. Listed at the end of the articles are the sources of the original research.

- Professional journals and trade publications can also be good sources of information. Your library has an Index of magazines and journals, as well as a directory of professional associations. Most associations have their own publications, with information that may not yet have appeared in textbooks.

Tips for Finding Reputable Research

The Judges will check to see if you used original research. What is original research? It is a research project that followed the engineering design process.

- Remember, your number one goal is to find original research. Don't get discouraged if this takes time. Just follow the instructions below and you will find what you are looking for.

- For your science fair project, it is important to stay focused on one task at a time, otherwise it can become overwhelming. Use your Design Notebook to stay organized.

- One way to stay on task when you are doing research is to use the Keyword Question Worksheet plus a few questions you wrote after meeting with experts and target users. Then research the answers to those questions.

- It is very important to primarily use scientific literature as references opposed to popular literature such as magazines and newspapers.

- Your library science teacher is a key person to help you find information. Uncover as much as possible about your project solution.

- Look at the date on the research pertaining to your subject. Science information gets outdated fast.

- During the time you are doing your research, keep a page in your Design Notebook that is titled: *Possible Supplies I Will Need for My Project*.

Library Research – the most valuable resource at a local library or college library is the librarian. Make friends with that person. In fact, make her your best friend. S/he will become an integral part of your networking team.

From the librarian you can learn to organize your research, how to search for information, how to read and use citations, how to narrow down web searches, and how to weed out the excellent and poor resources.

Some libraries have vertical reference services where you can chat online, email or talk on the phone to a reference librarian.

- First get an overview of what your subject is about. General information can be found in a dictionary, encyclopedia or textbook for each of your keywords. There are also specialized dictionaries and encyclopedias such as science, music, sports, etc.

- At your local library or college library you will find periodicals (magazines and newspapers). Look to see which articles have resources listed at the end of the article. Bibliographies at the back of an article or books list sources that can lead you to original research.

- If you live near a university that teaches engineering, they will have copies of their graduate students' theses.

- Many school or local libraries pay a fee to use online resources that are not accessible to the public or are too expensive to join. You can use the program in the library or sometimes login with your library card number. I have found that "ERIC" is an excellent program to use to find original research.

- Most libraries, whether they are small or large, are part of an interlibrary loan program where they loan books and periodicals for a specific period of time. Sometimes there is a small fee per book ($1.00). Ask your librarian about their interlibrary loan program.

- Most books have a table of contents and an Appendix. Check these sections to see if a book has the information you need.

Internet Research – The Internet can be a valuable resource, but you need be careful of where the information originates. Textbooks and other publications typically go through a rigorous fact-checking process, but for much Internet material, there is usually no comparable effort.

- **Internet Safety Tips <u>Before</u> Doing Your Research**: Discuss this section with your parent(s).

  Do not use your home address, telephone number, usernames, screen names, birthday, school name, your name or any personal information that could identify you in your email address.

  Nothing is private on the Internet, not even blogs! So, don't reveal any personal information about yourself. And don't put your photo in a blog or online.

  Never engage in an online communication with a stranger, even if s/he says they know your parents, teacher or friend of a friend.

- Search engines are excellent ways to search by keywords on the Internet.

  They try to index everything.
  http://www.google.com
  https://www.bing.com/
  http://www.yahoo.com
  http://www.refseek.com/ academic search engine for students and scholars
  http://www.rasmussen.edu/student-life/blogs/college-life/15-educational-search-engines/

- Subject Portals are more selective then search engines and list a small part of the information. The sites have been checked for relevance unlike the search engines. Here are the most popular:

  http://lili.org/ - Librarians' Index to the Internet
  http://vlib.org/ - The WWW Virtual Library

- Organizations and societies have online databases. If you give them a phone call, many of them will help with up-to-date resources.

- Take accurate notes on your note cards. List all the references, where you found them, name of reference, author, date, etc.

- Evaluate each source and decide if it is an excellent or a poor source:

Excellent References	Poor References
Comes from a credible source. The information makes sense.	Comes from a source with poor credibility.
The researcher is an expert in his/her field.	Person researching or writing the reference is not an expert in the field.
Researcher does not have vested interest in the outcome of the test results.	The researcher works for the company/subsidiary of the company that manufacturers the item.
Has up-to-date information.	Has out of date information.
Is not biased – doesn't take a point of view.	Is not objective and fair – takes one point of view.
Does not have errors when compared to other resources.	Has errors when compared to other resources.
Cites the original source in a proper way.	Does not cite where the information came from. Has no index or resources listed.
The reference material is easy to find.	The reference material is difficult to find.

Tips on Using Search Engines - Often times your search brings up too much information or too many irrelevant sources. Here are some tips on how to narrow your search and get specific information about your subject matter:

- **Do a very specific keyword phrase search**. For instance, if you are planning on designing a propeller free wind turbine, this is too general of a search term.

How about … **propeller free vertical wind turbine**. If you get too many extraneous sources, then put your keyword phrase in parentheses: **“propeller free vertical wind turbine”**.

- Site that gives you search tips:
  http://www.lib.berkeley.edu/TeachingLib/Guides/Internet/FindInfo.html
  https://support.google.com/websearch/answer/2466433?rd=1

Do a Patent Search

Letter “W” on the Timeline

Read the information about patents on the U.S. Patent & Trademark website.
http://www.uspto.gov/patents-getting-started/general-information-concerning-patents

Find out what patents are and why they are important to know about.
http://pragmaticmarketing.com/resources/what-are-patents

Find three patents that are similar to yours. Write the information requested in the Patent Research Worksheet printable. After you completed filling in the worksheet, attach it to your Design Notebook.

Background Research Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

Check off the outcomes you accomplished.	✓
I found at least 3 original research resources related to my problem / product.	
The answers to my research questions gave me the information I need to design my product.	
I took notes on note cards about what I uncovered.	
I filled out the Bibliography Worksheet for each resource that I found.	
I have at least 3 sources related to my problem.	
I found at least 3 patents that are similar to my solution.	
I filled out the Patent Research Worksheet.	
I documented all my activities and attached all my worksheets in my Design Notebook.	
I plan to research how my product will work, how I will design and make it.	

You know the drill by now. After you have checked off all the above statements, then you can take a break before moving on to the next section of this book. Have fun!

Step 3. Brainstorm Ideas & Develop Possible Solutions

Letter "V" on the Timeline

Propose an idea for solving the problem and explain why you believe it will work. Whether you work by yourself or on a team, develop as many solutions as possible. This is the time to encourage wild ideas and defer judgment! Build on the ideas of others! Stay focused on the topic. Have one conversation at a time.

This is a fun process because aside from examining solutions that already exist, you also get the chance to brainstorm with others, find analogies to the problem you're trying to solve, and sketch and scribble using lots of paper and big colorful markers.

Caution: You may fall in love with your first idea, but <u>do not</u> be tempted to settle for it. If you want to be an excellent designer, come up with as many solutions as you can. Then you can choose the one that you think is best.

Different Ways to Develop Solutions

- **Brainstorming, Ideation for Teams**

  There is one rule to follow and it is of the upmost importance that you abide by it: Do not comment, judge or criticize any one's ideas. This is a free-flowing process and if you interrupt, you will disrupt the creative thinking process.

  Ask one person to volunteer to be the recorder. Get a large sheet of newsprint. Tape it to a wall using painter's tape.

  As a group/individual, state what solution you want your product to solve. Write it at the top of the newsprint.

  Then, everyone gives ideas and the recorder writes them on the paper exactly the way s/he was told. **No comments are allowed**. This is a really fun experience because the ideas can be crazy, wacky and insane.

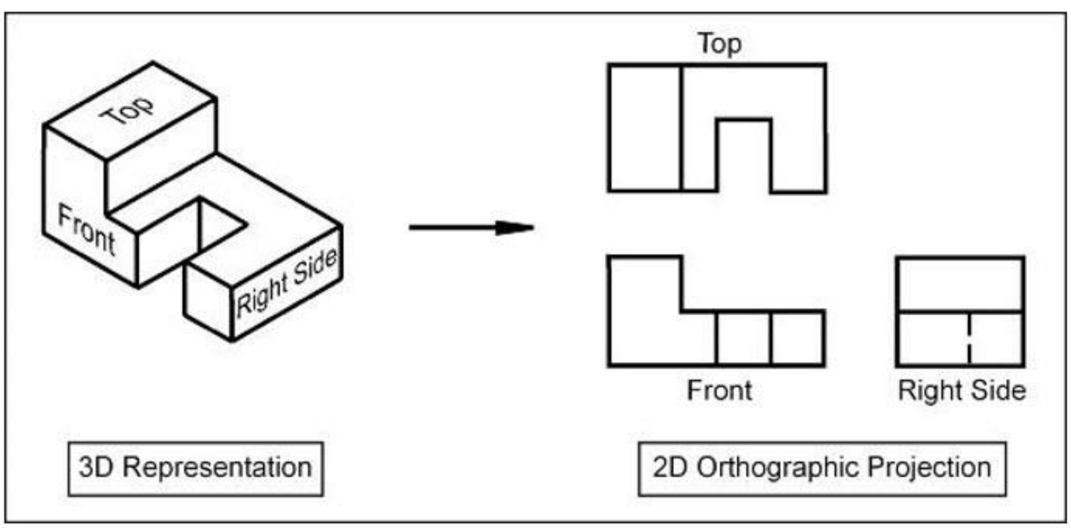
  When everyone runs out of ideas, then start at the top of the list and ask the question of each solution that was written, "Does____________ solve the need?" If yes, then leave it on the list. If no, then cross it off the list. No comments, judgments or criticism are allowed.

Whatever ideas that remain on the list at the end of this process are possible solutions.

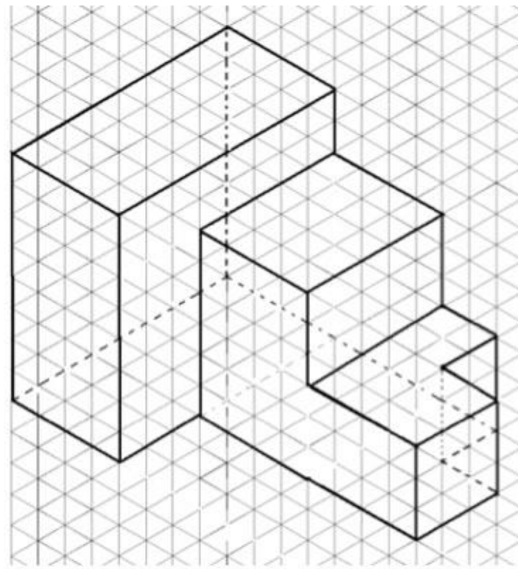
- **Doodling and Sketching**
  Whether you are working by yourself or in a group, each student needs to sketch his/her own ideas in their Design Notebook as the group discusses ways to solve the problem. Labels and arrows need to be included to identify parts and how they might move. These drawings need to be quick and brief.

  Each student must develop two or three ideas/designs using available technology, modifying current designs or inventing new solutions. You can create a superior project by demonstrating what is called, a *tradeoff analysis*. (compare the strength vs. cost of a particular material).

  Create new drawings that are orthographic projections (multiple views showing the top, front and one side) and isometric drawings (3-dimensional depiction). These are to be drawn neatly, using rulers to make straight lines and parts proportional. Parts and measurements need to be labeled clearly.



https://static.sdcpublications.com/multimedia/9781630570521-sample/ege/ortho/ortho_page1.htm



https://www.pngbarn.com/png-image-smumf

- **Analogies**
  Create analogies to describe your problem. Example:
  How would a dam design a faucet drain?
  Give an answer: A dam would design a faucet drain so that it was porous.

  How would a sponge design a faucet drain?
  Give an answer: A sponge would design a faucet drain with very thin capillaries.

  How would Twitter design a faucet drain?
  Give an answer: (your turn)

- **Examine Existing Products**
  When looking at the existing product, ask yourself, “What can I do differently to improve this solution?” A “what question” trances your brain so that it comes up with creative solutions. Maybe you can look at two solutions and see how putting them together will create a new excellent solution!

- **Sleep On It!**
  Whenever I have a problem of any kind, I put a piece of paper and pen next to my bed. In the evening when I go to sleep, I ask a “what question”. Most often

an answer comes to me in the middle of the night. Try this for a couple of days. Then you can brainstorm about what you dreamed.

Remember to document what you did today in your Design Notebook.

Specify Your Design Requirements

Letter "U" on the Timeline

Design requirements state that the important characteristics must be met in order to be successful. If you will be working with companies that have federal safety requirements, you may have thousands of requirements. But for a school science fair three to five will be fine. Do not make a lot of design criteria because then your project will become overwhelming.

- **What to Include in your Design Requirements**
  1. A complete description that will make your design successful.

  2. All your requirements, when put together, must work as a whole. Consider the cost and your budget, the space size where the product will be used, and the need.

- **4 Types of Products You Can Analyze**

  Your design requirements must include the problem you want to solve. It is important to know all the needs of your target users. Then turn your design into the solution that will solve the problem.

  Your design product will fall into one of these categories:
  1. **Physical Product** – a product you will improve from one that already exists. If you are improving upon a product the best way to identify your design requirements is to take it apart (with permission) from the owner or designer and exam a similar product. Take photos of the put together product and each of its parts. Analyze how it works.

  2. **Software Product or Website** – analyze how to complete a task in the simplest and easiest way. Example: how to determine shipping weights in real time in a shopping cart checkout page.

3. **An Environment** – how to use or create a space that is more effective and easier to use. Example: working space in a large office building.

4. **An Experience** – an event, interaction or a particular portion of time you want to improve for users. Examples: A first time student goes away to college; how people can communicate most effectively when working on an international team.

- **Identify the Need and Constraints**
  Letter "T" on the Timeline

  As you gather your research, determine the design criteria and constraints of your project. Design criteria are requirements you specify for your design that will be used to make decisions about how to build the product.

  - **Design Criteria**
    You need to be very specific when you describe the design requirements (criteria). The criteria are derived from the needs expressed by the customer. The criteria define the product's physical and functional characteristics. Include the Universal Design Requirements:

    Size
    Appearance
    Physical Features
    Performance
    Use in Environment
    Shape
    Weight
    Speed
    Ruggedness
    Ease of Manufacture

  Example of a statement: "Our growth chamber must have a growing surface of 10 square feet and have a delivery volume of 3 cubic feet or less." [NASA]

- **Constraints**

  Constraints are factors that limit the engineer's flexibility. You need to list the limits of the design due to available resources and the environment (constraints): time, cost, safety, knowledge, legal issues.

  When you write your criteria, divide it into categories. Each industry has its own requirements. Do a search on the Internet or contact an expert to find out what you need to know. Wikipedia is helpful. Here are examples to give you an idea.

  Cost – to purchase, to user, to repair
  Size – overall dimensions, dimensions of parts
  Physical Characteristics - weight, density, color, transparency
  Environmental Requirements – water resistance, operating temperature
  Performance Characteristics – accuracy, strength, speed, friction
  Inputs – energy consumption, labor, fuel consumption
  Outputs – power, pollution, undesirable side effects
  Manufacturing Considerations – equipment needed, labor requirements

Write Your Design Brief

Letter "S" on the Timeline

You will need to write a design brief. This is simply a document that contains all the key information for solving the problem or need you have identified. It will gather all the information you researched and simplify it into one condensed summary. Include the following:

- Description of your target user.
- Definition of the problem you want to solve.
- The target user.
- The requirements of your solution.

Take out your Design Brief Worksheet printable to write your Design Brief. Then, attach the Design Brief Worksheet to your Design Notebook. Date the entry.

Proposal Form Worksheet

Letter "S" on the Timeline

Fill in the all the required information in the Engineering Design Process Proposal Worksheet printable.

Print 3 copies: one for your teacher, one for your parent(s), and one for your Design Notebook.

Your teacher may ask you to make some changes or she may not approve the proposal the first time. Better now than after you built your solution.

The Proposal Form helps to keep all communication clear and upfront. Thoughts and words get "lost" when they are just verbal. This way everyone is on the "same page" and there will no misunderstandings. The form is like a contract between all the parties that sign the form and a great protection for you.

The following are also for your meetings.

Possible Solutions Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

Check off the outcomes you accomplished.	✓
Check the following strategies that you used to develop solutions for your problem: ◦ Brainstorming/ideation ◦ Doodling and sketching ◦ Analogies ◦ Examination of existing products ◦ Slept on it!	
I wrote the Definition of the Problem which includes: ◦ How existing products are used and why they fail to address the problem ◦ Description of the target user.	
I specified my design requirements listing a complete description including the cost to build, my budget and space size where the product will be used and needed.	
I identified and made a list of the design criteria and constraints. My solution meets the following universal design criteria also:	

2nd Meeting with Teacher and Parent(s)

Letter "R" on the Timeline

This is an important meeting. Be prepared. Continue to show your enthusiasm. Bring the following with you to these two meetings plus all the information that you believe will show that you are serious about completing your Engineering project.

- Possible Solutions Outcomes Checklist
- Design Requirements (listed in Design Brief Worksheet)
- Design Brief Worksheet
- Proposal Worksheet
- Design Notebook
- Great smile that comes from within and lights up the room!

Are your worksheets stapled or taped into your Design Notebook in the order in which you completed them? Be sure they are dated.

Discuss whether or not the project is possible to complete by the deadline. Take into account the possible cost and equipment needed.

If both your teacher and parent(s) approve, then you can move ahead and make your drawings and build the prototype. Make sure that both your teacher and parent(s) sign the Proposal Worksheet.

Step 4. Design Your Solution(s)

Preparing a Preliminary Design

"Q" on the Timeline

For many, this is a challenging step.

Before Doing Your Drawings

Once you have eliminated the designs that did not meet the requirements, you're ready to get down to the nitty-gritty of refining and improving your solution. Depending on the form your solution will take, you could make drawings, lay out your design in a storyboard format, or construct a model or prototype… an operating version of your solution. Whichever way you choose to design your solution, remember that engineers always sketch out their ideas to show what they will look like when they are done.

Decide how you are going to <u>measure</u> the change your invention will make because it is important to present evidence that the change occurred. You will need to include this in the data section of your Project Report.

Revisit the needs, constraints and research from the earlier steps. Make a list of all the alternatives. Compare your best ideas. Select one solution that you think

- best solves the problem
- is the most functional
- is the most visually appealing
- is the most cost effective yet uses excellent materials
- meets all safety requirements in its particular industry

Other factors to consider:

- Do I have permission to create this design?
- What materials do I need and are they available? Can I afford them?
- Do I have enough time to build and test my prototype and write my project report?
- If I use living things, will they be safe?

Add any additional attributes that you believe are important.

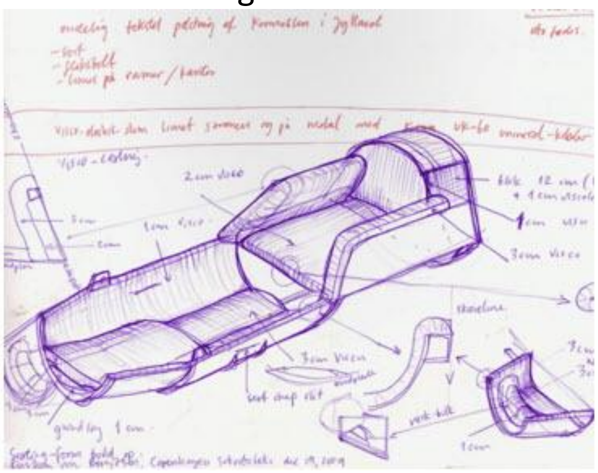
Make a chart showing the attributes and each solution.

Methods of Development

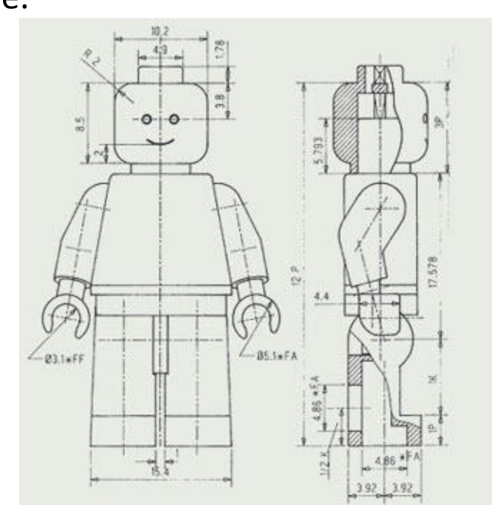
- **Drawings**

  You may be thinking, but I cannot draw. Well, you are not being asked to be an artist. Engineering drawings are really just lines that form basic shapes put together in the form of an object. Take a breath and enjoy the process. YouTube has instructions on how to make engineering drawings. Here is a basic one.

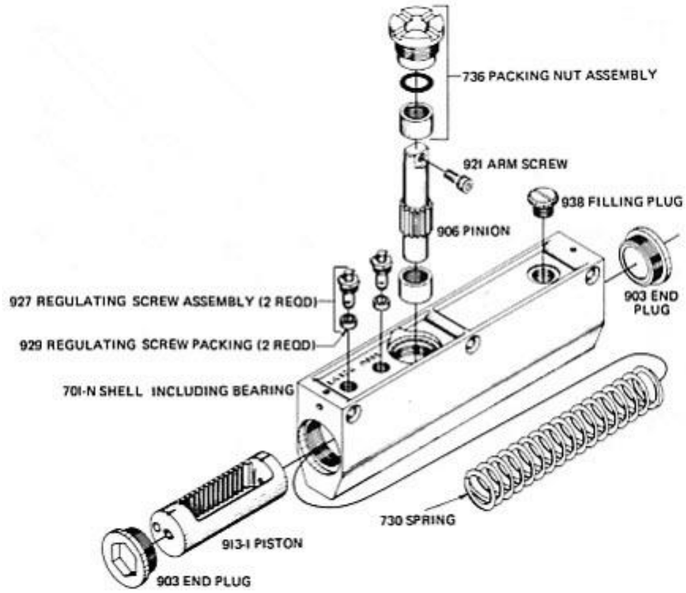
  - **Sketches** - rough freehand drawings that show outlines of the object.



  - **Technical** - also known as drafting or draughting, is an accurate way of drawing that visually communicates how something functions or is to be constructed. It shows its true size and shape. It usually uses computer aided design (CAD) software.



- **Pictorial** - the oldest written method of communication known. A major value is that it shows objects three-dimensionally. Engineering **drawings**, with all their dimensions and multiple views, are usually difficult to read for an untrained person.



Make your design drawings in your Design Notebook. Attach the technical or pictorial images into the design book.

- **Prototype**

  A prototype is a working model of your invention with which a user can interact. A good prototype allows you to test your idea and make sure it works in reality as well as in theory. By building a prototype and using it to test your solution, you reduce the risk of it not working. It enables you to receive input and improve your design.

  Inventors generally go through three types of prototype designs and creations.

  1. The ***crude prototype*** **or model** is a very basic model that allows you to get a better idea of how your invention will work. This does not need to be a working model; its job is simply to allow you to think about how your invention will function. Going through this process may give you ideas on how to improve your invention's functionality.

Make a model to scale to see how to make the parts the right proportion when you build the prototype. Remember, the model is not a functioning product. It is like building a model airplane that doesn't have a real motor and cannot fly.

Another type of model can be built on your computer. This is especially helpful when you are working on solving complex problems.

2. A ***working prototype*** is the next step and it doesn't need to be perfect, but it must allow users to go through the steps required to move from Point A to B. The working prototype must also be able to perform some real-time functions. Unless your invention is one that can be created from materials to which you have access—i.e., zippers, fabric, or wires—you may need to seek the help of a third-party in its creation.

   A great innovation in the creation of working prototypes is ***3D printing***, also known as ***additive manufacturing***. This process allows for the creation of working models faster and less expensively than ever before. Making changes to working prototypes through this method is also much less of a hassle.

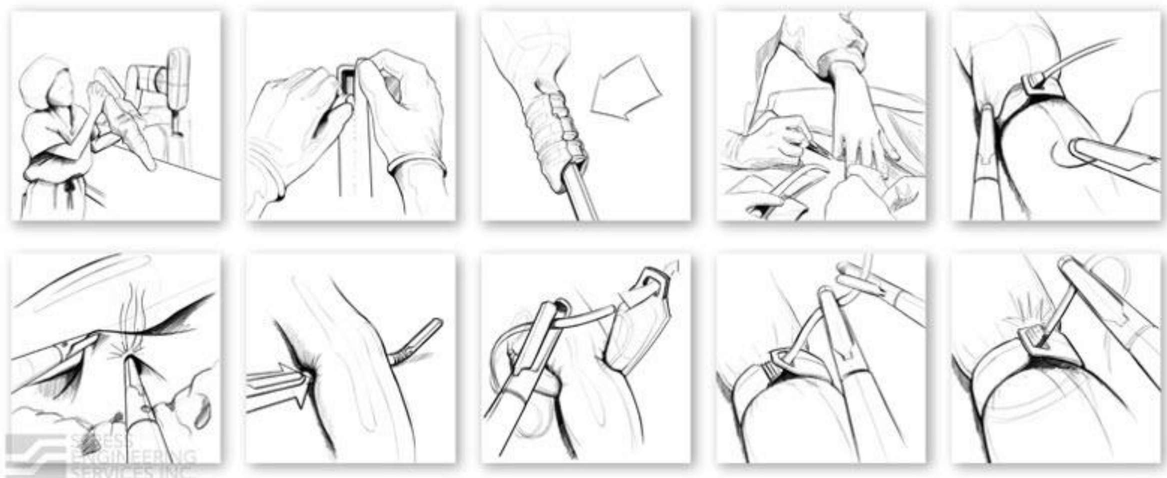
3. The ***final prototype***, or ***prototype manufacturing***, is a mock-up of the new product to be introduced to the market. It looks and acts just like the production unit, following the specifications that will be used in the mass-manufacturing of the product. Most manufacturers will create a final prototype as one last check that all the pieces fit together to create a functioning product.

   Is the final prototype really the final model? Nope. The last step before full-scale production is called ***prototype manufacturing***, or pilot production. These models are created using short-run manufacturing technology and may be used for broad field testing.

- **Storyboards**
  A storyboard provides a visual description of the use of a product. Like a cartoon, it is a series of images or illustrations. In the context of an engineering design, it shows how users interact with the solution. It helps you to better

understand user groups, context, product use and timing, while communicating about these aspects with all the people involved.

At a glance the whole setting can be shown: where and when the interaction happens, the actions that take place, how the product is used, and how it behaves, and the lifestyle, motivations and goals of the users. Storyboards allow you to literally point at elements, which helps during the discussion.



http://innovation.stress.com/images/portfolio/med_storyboard.jpg

There is also software you can use if you have a complex problem.
http://www.slideshare.net/sandrasukarieh/storyboarding-information-systems-engineering

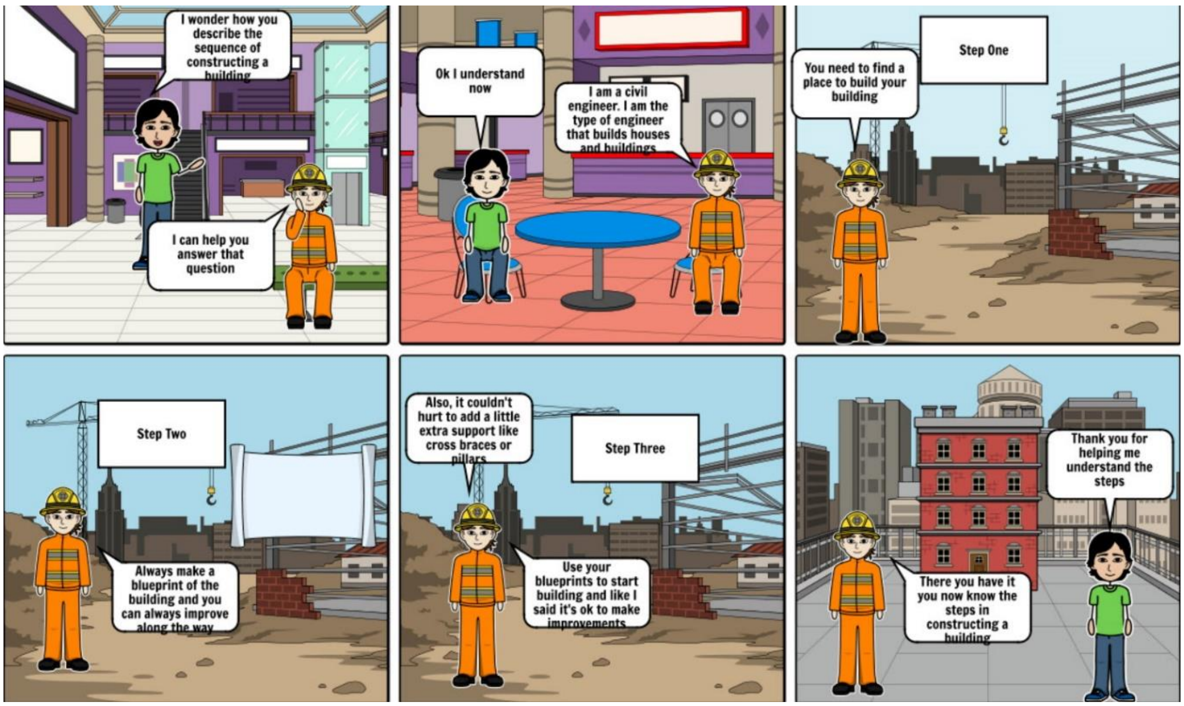
Use of Storyboards

You can also use a storyboard at various stages of the design process. During the research stage you can use it to analyze your problem by showing how the problem occurs over time and the interaction with the user or in an environment.

Create a storyboard when you design your initial prototypes to help you compare the designs. Include how the target user will use the solution. Below you can see how Georgetown University students used a storyboard to show how to reduce waste in the school.

See Types of Engineering Drawings and Engineering Drawing Components in the Appendix.

StoryboardThat.com also has a dynamic program where you can create your own storyboard: https://www.storyboardthat.com/storyboard-creator. Below is one that a student created on this site.



You will need to do a presentation to your target user, classmates or at the science fair. A storyboard is a great way to show how the end user interacts with your product or system that you designed. Breaking down the stages using a visual presentation makes it easier to explain and understand.

Choose the Best Solution

Letter "P" on the Timeline

Considering Each Engineering Design Solution on Its Own

By means of a qualitative or quantitative rating system, you will select a final design.

As you focus on one type of design, you need to show the changes needed as the designs get closer to the requirements and expectation of the prototype. The changed designs need to show progress from design to design.

- First, establish the requirements needed for the development of the prototype to decide how it will be built.
    - Does it meet your design requirements? (shape, size, weight, appearance, physical features, performance, use, cost, time and money)
    - Does it do a better job than others in the marketplace?
- Second, make a list of the features that would be nice to have as part of the solution. These solutions are not necessary, but might make your product better.
- Third, include the **universal design criteria**: robustness, elegance and aesthetics; cost, time and resources; safety and required skill; robustness. Read about The 7 Principles of Design here…

Share and discuss amongst the members of the team. Record pros and cons of each design idea directly on the paper next to the drawings.

Design Matrix

Letter "P" on the Timeline

To help you compare solutions you may want to create a Decision Matrix. It is a brainstorming method that helps students uncover solutions to engineering problems. It is a chart with the design criteria on one axis and the various solutions on the other.

Take out the Design Matrix printables: Directions, Template, and Comparing Alternative Designs Template.

Include in your design matrix the design requirements at the top of the list (must have), nice to have solutions, and universal design criteria. Use a simple numeric scale to rate each solution and write each rating with a different color pen: (**0** = doesn't meet the criteria, **1**= somewhat meets the criteria, **2**= definitely meets the criteria).

After you complete filling in the matrix, remind yourself of the prototype expectations and how it will be tested to meet the desired expectations. Or you may simply list the pros and cons of implementing each solution.

Click on this link see a student's completed Design Matrix. It will help you to navigate through this process.

Here are 2 more types of matrix design templates:
https://usaidlearninglab.org/library/evaluation-design-matrix-templates

Remember to record in your Design Notebook how you chose and evaluated alternative designs. Ask yourself, "Can I defend my choices to the Judges?" If you used a Design Matrix, attach it in the Notebook.

Materials List

Letter "O" on the Timeline

Overview
The Materials Supply List is different than the shopping list. The Materials list is only for those items that you will need to make your solution. The Procedure includes both the Materials List and the Procedure. This list will be included in the Build and Test Your Prototype section of your Project Report that you will write after you have completed your solution/product.

Example
Here is an example of a good (not excellent) engineering science fair materials list for building a solar hot dog cooker.

- Oversized shoe box
- Aluminum foil
- Poster board
- Scissors
- Craft knife or box cutter
- Tape
- Glue
- Pencil
- Ruler

- Skewer
- Single hole punch
- Sheet of graphing paper
- Hot dogs, buns, and your favorite hot dog condiments!

Here is what needed to be added to the list to make it even more specific. It makes it an excellent materials supply list:

- 8” x 12” shoe box
- Standard weight aluminum foil (not heavy duty)
- 12” x 12” poster board
- Scissors
- Craft knife or box cutter
- Masking tape 1-1/2” wide
- Elmer’s white glue
- #2 pencil
- Yardstick ruler
- 8” stainless steel skewer
- Single hole punch
- 8-1/2” x 11: graphing paper
- All beef hot dogs, buns, and your favorite hot dog condiments!

Details of How to Make Your Materials List

Good cooks have all their ingredients assembled before they begin. A student “cooking” up a science fair project also needs to have all supplies and equipment on hand. That’s why it’s so important to create a list of everything you’ll need before you start your project.

Make a detailed list of all the materials and equipment you will use for building the prototype. Use descriptive words to describe the materials and equipment. It is important to list the manufacturer, the size, shape, weight, color, and dimensions so that another person will be able to duplicate your invention or program. (Example: 2 wooden pine boards, 2” x 4” x 9”)

Record the list in your Design Notebook

The 2nd time you build your prototype Engino Engineering and Mechanical Systems, Lego Building Bricks, Lego Mindstorms and Lego Technic are excellent construction kits. Fishertechnik is really good for more complex models and will hold together better than Lego. Meccano parts are made of metal and they bolt together.

Breadboards are used to build electrical circuits. Snap Circuits allow you to design your own circuits using the parts in the kits.

If you were a stranger looking at the list, would you be able to replicate exactly what you used? If not, go into more detail.

Add all your materials and supplies to **Shopping List 2**. Print and save that list and bring it with you to the 3rd Teacher and Parent meeting.

Materials List Checklist

Print this page, check off all the outcomes, attach to your Design Notebook and date your entry.

I Wrote An Excellent Materials Supply List Because…	✓
I listed every single item that I need to build my prototype.	
I listed the measurement of each item on the list (size, millimeter, centimeter, ounces, pounds, brand of item, manufacturer, etc.).	
I described the materials I am going to use in enough detail so that the prototype can be duplicated exactly as I designed it.	
I entered all the above information in my Design Notebook.	

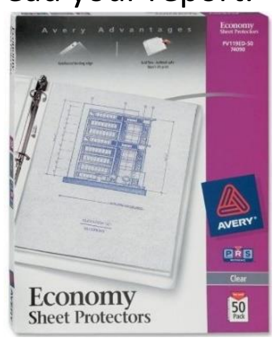
Do not move on to the next step until you can check off all the above 4 items.

Shopping List 2

Letter "N" on the Timeline

- Add the items on your Materials List to the Shopping List 2 list.
- 3-Ring Notebook with at least one pocket on the front cover. Used to store your Project Report and place on your table at the fair. Coordinate the color of the folder with your display board colors.

- 1 - box of 3-ring clear Economy Weight Sheet Protectors
  Used to protect your Project Report pages from tearing or ink smearing when Judges, teachers and others read your report.



- Tabbed Dividers
  Use to separate sections of your Project Report (if purchased this in Shopping List 1, do not have to purchase it again)

- White Computer Paper
  Used to print your Project Report and pages that go on your display board.

- Computer Ink Cartridges
  You want to make sure that your printer prints sharp font and images.

- Display Board
  Standard size tri-fold display boards are 36” x 48” for school fairs. Do not purchase a flimsy board because it will keep on falling down. Elmer’s Tri-fold is

the best quality board. You can get one that is corrugated cardboard or foam. They come in white and in an assortment of colors.

Look in the section of this book that shows you how to do an outstanding display board before you order any materials. A Teacher's Store in your neighborhood, Blick, Walmart and Target may have tri-fold boards.

- Companion Board w/Stand
  If you are going to do a complicated project or are going to attend a top science fair, it is a wise to do a Companion Board that will help you to summarize key points. It gives you the ability to explain a complex project to a judge who probably will not know the intricacies of your project. The board stand will hold a 20" x 30" flat board. We will go into detail on how to make a companion board later in the book. (see next page)

- **Headers for Display Boards**
  Help your board to stand out in the crowd and give you more room to put a unique title on your display board. It sits at the top of your display board. Choose one that is manufactured by the same company as your display board so that it inserts securely. The header also helps the tri-fold board to not tip over.

- **Construction Paper** (click on link for color options)
  Use color construction paper to place behind your printed material. It will act as a border for the sections of your report. Choose only one color.

- **Adhesives**
  Do not use Elmer's liquid glue because it will cause the paper to pucker. Rubber cement is a better choice. Here are more professional options.

[Dual Tip Glue Pen]

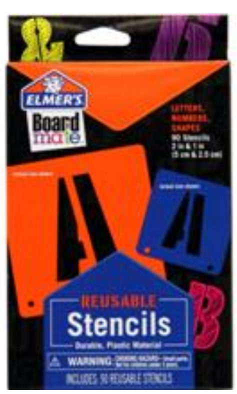
[Glue Stick]

[Spray Adhesive]

[Mounting Tape]

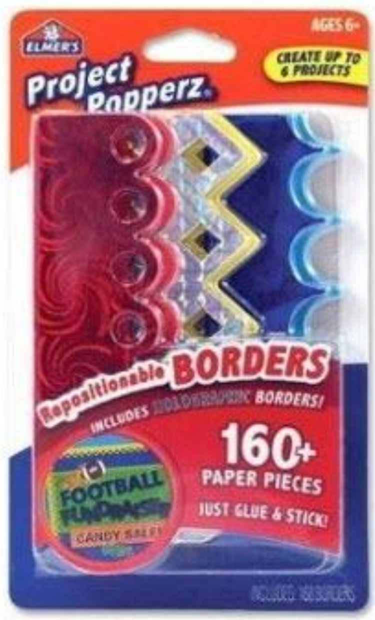
- **Materials for Title Tags and Border**
  The following materials make your board look professional and stand out at the science fair. Self-adhesive repositionable letters are the best, but if you cannot afford them, then use a stencil and construction paper or **dual color markers**. (See below)

  Look here to learn the [size lettering for each section of your board]. Do not make your board busy with a lot of different colors. Choose one color for the title and subtitles.



[Letters & Numbers] [Stencils] [Markers] [Jumbo letters] 4" high

You may want to add a border made out of construction paper or a repositionable colorful boarders adds a nice effect, but make it the same color as your title and subtitle.



- **Photos**
  Plan to take photos of your equipment and supplies. Include them in your Project Report. Judges love photos. Do you remember the *Success is a Journey* story? It told you another important reason to take photos.

  If you do not have a cell phone or digital camera, consider purchasing a disposable cell phone or disposable digital camera to take pictures.

Write a Step-by-Step Procedure

Letter "M" on the Timeline

Write a step-by-step procedure that you will follow to build the prototype. Write it in numerical order. Be very descriptive in your writing so that another person could replicate exactly the model you are going to build.

Print and save this list to bring with you to the 3rd teacher and parent(s) meeting.

If you make modifications as you build the model, write the changes in your Design Notebook.

Preliminary Design Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

Check off all the outcomes you accomplished.	✓
Before I designed my solution, I reviewed my research, needs and constraints.	
I compared the best ideas and selected one solution that solves the problem, is most functional, is cost effective, is visually appealing and meets all safety requirements.	
I made a chart showing the attributes for each solution before I made my decision.	
I chose from the following methods of development ◦ I made drawings, drew sketches, used CAD software to create a pictorial representation. ◦ I created a crude prototype. ◦ Made a storyboard.	
I made my materials & supply list and added it to the Shopping List 2 page.	
I wrote a step-by step procedure for making my working prototype.	

3rd Meeting with Your Teacher and Parent(s)

Letter "L" on the Timeline

Get your teacher and parent(s) approval before you build your working prototype.

Bring the following to these meetings:

- Materials List & Shopping List 2 List
- Step-by-Step Procedure
- Preliminary Design Outcomes Checklist
- Engineering Design Process Proposal Worksheet
- Your smile and enthusiasm

After both meetings have been completed and you have approval from your teacher and a parent, it is time to go shopping. Ask a parent to accompany you while you make your purchases. It is illegal to use a charge card and sign for the purchases if you are not 18 years or older.

- Some items will be easy to obtain. Others will require a little shopping, either at a store in your neighborhood or on a website. If supplies need to be mailed to you, make sure they will arrive on time so you can meet your project's deadline. It's frustrating to have to stop in the middle of a project because of some item you forgot.

- Hospitals, high schools, community colleges, universities, manufacturers or your science teacher sometimes will allow you to use equipment under supervision. If your parent(s) or teacher do not have contacts at one of these institutions, then ask your parent(s) or teacher to help you network to find someone who does. If a doctor or scientist is interested in your project, they may also mentor you. Don't be shy, ask around. It will be worth the effort.

If You Plan to Enter a Big/Top Fair

After you have your 3rd meeting and get approval from your teacher and parent(s):

If you are going to enter a specific engineering science fair like the ISEF, now is the time to mail in your application. Each of the fairs has its own criteria so go to the websites to get the information and application.

The application forms are different for each of the following fairs and the link for the application form changes every year. The best thing to do is to go to the below link, find the fair you are interested in applying to, then search for that form. Read the Science Fair Directory list and decide which Top Fair(s) you want to apply to.

Most top fairs require you to list your project in a category of science and subcategory of science. Look at Intel's list here...

If you have never been to a top fair, look in the Appendix to see what they look like. Prepare yourself… it is a huge event in a very large auditorium.

Step 5. Build a Working Prototype (Solution)

"K" on the Timeline

Before You Begin to Build Your Prototype

All professionals prepare before they begin their work. A chef makes sure his workspace is clean and then places all the ingredients on the kitchen counter before preparing a dish. The same is true with an engineer. Here is what you need to do before you begin building your prototype.

- With your parent's permission, set up a special place in your home. This place must be out of reach to siblings and/or pets. It is a permanent place that will not be needed by any member of the family until you are finished building and testing your prototype.

  Arrange for a family meeting to explain the importance of your "hands off" policy.

- Read your step-by-step procedure until you are confident that you understand what to do for every step. If you have any questions or doubts, ask your parent or teacher to help clarify that step.

- What to put in your workspace.
  1. Design Notebook for taking notes and collecting data for your data table.

  2. All materials, equipment and supplies you will need so that they are easily accessible. If you are missing anything, now is the time to get them.

  3. Be safe.
     - Are you using equipment that is sharp or can hurt you? If "yes", then ask an adult to be present when you use this equipment.

     - Use laboratory grade goggles, gloves and smock when necessary.

     - If your hair is long, secure it in the back of your neck with a rubber band or hair band.

     - Do you need a fire extinguisher?

Important Information

- Do you have your Design Notebook so that you can record all observations of your procedure? Your teacher will expect to read it and it is one of the key items that you place on your table at the science fair.

- Prepare a data table before building your prototype. The data table is where you are going to record your trials. We will show you how to make a data table later in this book.

- Remember to follow your Procedure exactly as you wrote it. If you make changes along the way, then you <u>must</u> document it in your step-by-step procedure and note the changes in your Design Notebook.

- Remember to be accurate when you take measurements. If at all possible, numerical measurements are best.

- Take photos of every step that you perform of your experiment. You will be able to use them in your report and on your display board.

Building Your Prototype

This is the fun step, sometimes the most frustrating, and will take the most time. Build a prototype to make your ideas real!

Prototypes are created to reduce the chances of failure and optimize the chances for success by allowing you to test how your solution will work. **The prototype cannot be made from a kit.** Typically, the 1st prototype that you build is made with cheaper materials that are easier to work with than those that will be used for the final version. Cardboard, form-core board, mat board, paper and poster board are excellent modeling materials. This is a cost effective and efficient way to bring your design to life.

Use your **Design Matrix** to choose the design that best meets the criteria and considers the constraints. Then build your prototype. The prototype is either a full-size or a simple scale model based on your drawings. This will allow you to test your design. Your teacher can help you to identify and acquire appropriate modeling materials and tools.

The early versions of the design solution help you / your team to verify whether the design meets the original challenge objectives. Push yourself to be creative, imaginative, and excellent in design.

When you show your prototype to others, they can give their opinions about how your solution is likely to work in the real world. Be sure they understand that this version is close to the real thing, but not the thing itself.

Step 6. Test It

“J” on the Timeline

Before you begin testing your design know about….

SECRET FILES #6

Errors in a Measurement

A Simple Explanation

Definitions

All experimental uncertainty is due to either random errors or systematic errors.

- **Random errors** in experimental measurements are caused by unknown and unpredictable changes in the experiment. These changes may occur in the measuring instruments or in the environmental conditions.

  Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.

  Examples of causes of random errors
  - electronic noise in the circuit of an electrical instrument
  - irregular changes in the heat loss rate from a solar collector due to changes in the wind

- **Systematic errors** in experimental observations usually come from the measuring instruments.

  Systematic errors are difficult to detect and cannot be analyzed statistically because all of the data is off in the same direction (either too high or too low). Spotting and correcting for systematic errors take a lot of care.

  Examples of systematic errors in measurement
  - there is something wrong with the instrument or its data handling system
  - the instrument is wrongly used by the experimenter

  Examples of systematic errors caused by the wrong use of instruments are:

- errors in measurements of temperature due to poor thermal contact between thermometer and substance whose temperature is to be found

- errors in measurements of solar radiation because trees or buildings shade the radiometer

  The **accuracy of a measurement** is how close the measurement is to the true value of the quantity being measured. The accuracy of measurements is often reduced by systematic errors, which are difficult to detect even for experienced research workers.

Note that systematic and random errors refer to problems associated with making measurements. *Mistakes* are made in the calculations or in reading the instrument *are not considered in error analysis*. It is assumed that the experimenters are careful and competent!

Examples of How to Minimize Experimental Error

Type of Error	Example	How to Minimize It
Random Errors	You measure the mass of a ring three times using the same balance and get slightly different values: 17.46g, 17.42 g, 17.44g	Take more data.
	Using a 100-millileter graduated cylinder to measure 2.5 milliliters of solutions	Equipment used to make the measurements is not sensitive enough.
Systematic Errors	The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all the length measurements were too small.)	How would you compensate for the incorrect results of using a stretched-out tape measure?
	The electronic scale you use reads 0.05 too high for all your mass measurements (because it is improperly tared throughout your experiment).	How would you correct the measurements from improperly tared scale?
	Using a 1-quart milk carton to measure 1-liter samples of milk.	The volume would always be too small because a quart is slightly smaller than a liter.

Testing Your Design

This may be the most important step in the whole process. You will want to see if the prototype works the way you want it to. Does it solve the need?

For instance, if you build a tower, will it stand up the way you want it to? Does it stay standing up? If you build something with moving parts, do the parts work the way you want them to?

Work out the glitches, test with real users. The long road from identifying the problem to arriving at the solution is never a straight road. As you test your design prototype, you'll likely come across an obstacle that sends you looping back to work out an issue. The more people you use to test the product, the more feedback you will get and the faster you will be able to build your final prototype. <u>Always go back to your problem statement to see if your solution solves it.</u>

Don't get discouraged, your prototype will probably not work the way you want it to the first time. Engineers tweak and test their prototype over and over and over again, sometimes for months. That's why a lot of time and brain power go into the last step. Typically, this will happen again and again.

Even when you think you have come to the final version of your design, the journey continues. You must have 3 to 5 users test your solution in the environment where the problem occurs. You will want them to give you their honest opinions.

- What do they like?
- What do they dislike?
- Where could you make changes for the better?
- Did they overcome their problem with your solution?
- Did they have to ask questions to clarify certain steps?
- Where in the interaction did they ask questions?
- What were their questions?
- Did you meet your measurable targets?
- Did the solution work the way you wanted it to?

While the target users are testing the solution, it is important that you observe them. Look, listen, and feel (use your intuition) their experience. Record your observations in your Design Notebook.

Once they make the recommended changes, re-test to make sure the problems have been fixed. Be aware that even a minor alteration at this point can make a big difference in the end.

Develop a test plan describing what you will test, how you will test and how you'll perform the analysis. You must test your prototype under actual or simulated operating conditions. Customers are usually involved in product testing so be sure you have SRC's (Scientific Review Committee) approval if people are involved.

Analyze Data & Draw Conclusions

Record and Interpret Data

"I" on the Timeline

Data

The results section of your report is where you will tell your reader the actual numbers (or other data) that you got when you did your testing.

So, what is data? Data are the facts or bits of information that come from observing and testing. Scientists often use graphs or tables to show their data and research findings. Data can be numbers or words.

The purpose of tables and graphs is twofold: 1) help you to analyze and interpret your results and 2) enhance the clarity of your testing to a reader or viewer.

- Use tables to express the data and patterns. Ask yourself:

  - What can I learn from what the results showed?
  - Did you get the results you expected?

- Always have a title for your tables. Place it at the top of the table or graph.

- In your report, you can include more than one data table, as long as the format is clear and easy to read.

- Number the tables consecutively throughout your report.

- Take time to think about what your data tells you.

This is a great site to see different types of testing and data analysis. Also included are abstracts and reports. Go to the home page: http://www.nature.com . Scroll down on the page to **Latest Research**.

You can also go to the top of the page and click on "Search". A window will appear on your left. Insert the word, **Engineering.**

What is a Data Table?

A data table is an organized arrangement of information in labeled rows and columns. It is a useful way to present and display information about a group of related facts. It is especially useful in recoding observations made during a scientific investigation.

Organizing your results will allow you and those looking at your work to draw conclusions about the problem you are going to be investigating.

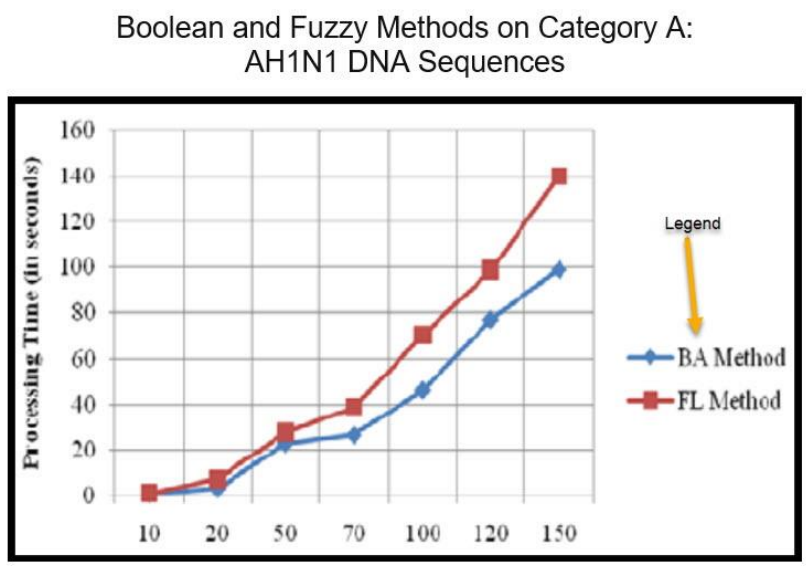
Types of Tables

- You can use graphs to express the results of your data. They are pictures that help us to understand amounts. These can be drawn on graph paper or on your computer.

- Place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.

- It is important to label the axes of your graph— don't forget to include the units of measurement (grams, centimeters, liters, etc.).

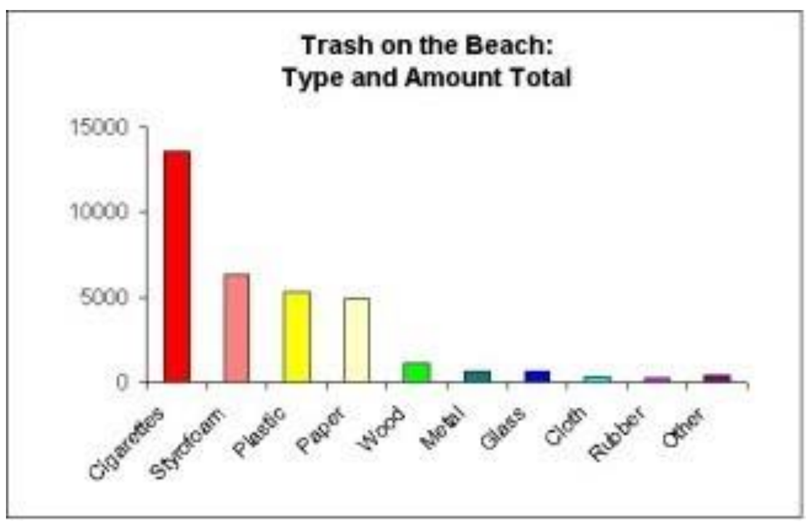
- If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.



Here are different types of graphs. See which graph is best show your data.

There are picture graphs and histograms, but for your science fair project, choose from one of the 3 pictured above.

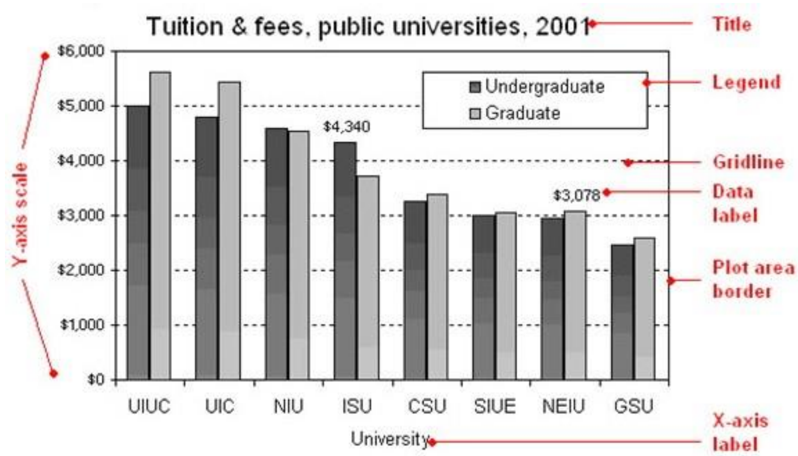
Bar Graph



How different are these variables to each other?

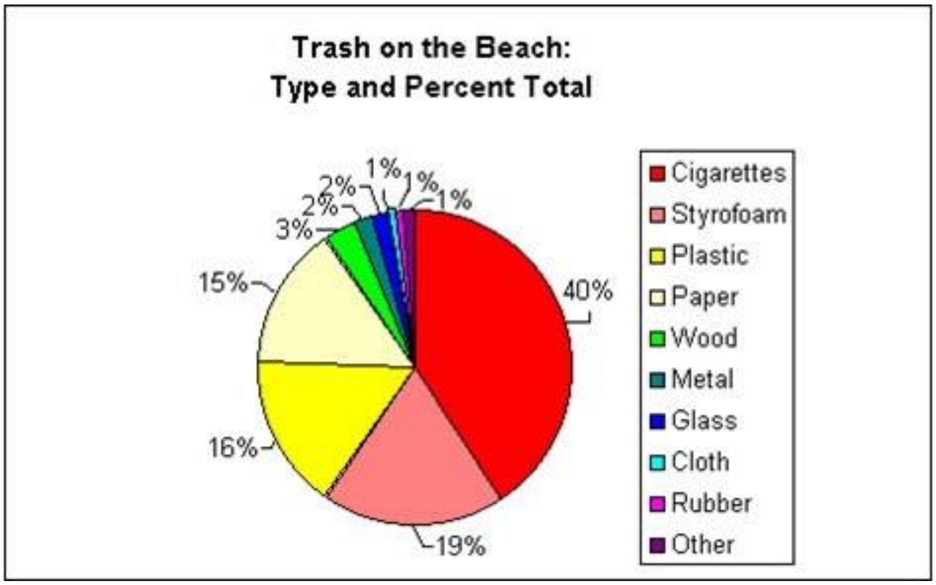
Bar graphs are great for looking at differences amongst similar things. In this case we are comparing types of trash. Bar Graphs are also good for giving a comparison of absolute numbers. A bar graph might be applicable for comparing different trials or different experimental groups. (In Microsoft Excel, generate bar graphs by choosing chart types "Column" or "Bar.")

Bar graphs are also excellent because you can stack numbers of things right next to each other and compare them instantly. In our example, the height of each stack can tell you the number of each type of trash that is found on the beach, either approximately, by the numbers on the vertical axis, or exactly, by labeling each stack with the exact number.



However, if we wanted to compare what portion each stack may represent of all the trash combined, we need a pie graph.

Pie Graph



What portion of the total does each part make up?

A pie graph allows us to compare parts of the whole with each other, or the fraction of the whole each part takes up. That might sound a bit complicated, but it's easy when you think about it in terms of a cake.

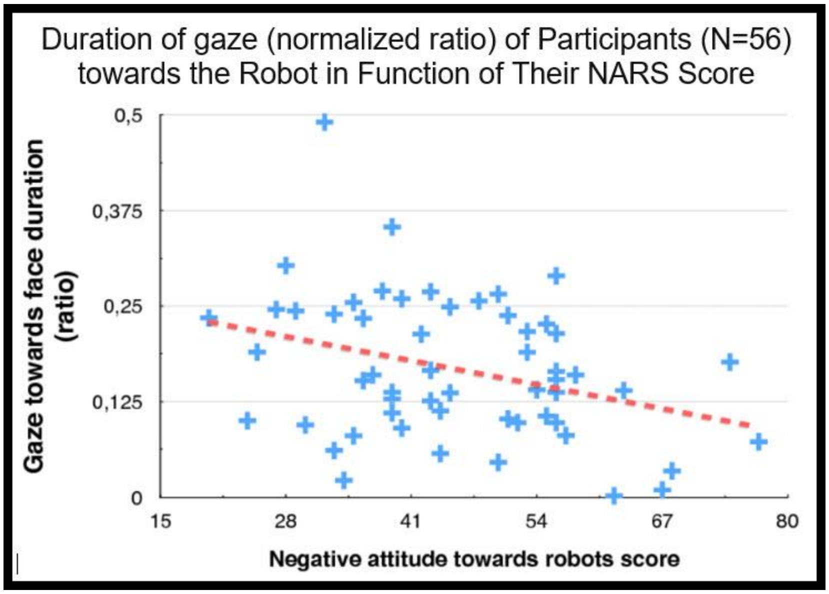
You're starting to pick up some real science smarts! You see, pie graphs represent data in a visual, easy to read manner, which helps us to understand data more clearly. Using this pie graph, we can see what portion of all the trash each particular type of trash represents (how big of a piece of cake each type of trash "eats"). It's as simple as that!

Even though graphs can look simple, there's a lot of information in a graph.
Let's say you eat half of the cake (Boy, you were hungry!), how much of the cake is left? (50%) Obviously if you ate one side of the cake, then the other side is still there. Let's say you weren't quite so hungry, so you only ate half of that half. (25%) How much is left of the cake now?

You get the idea. The most you could ever possibly eat is the whole cake (100%), because after that, there's no more cake left! The less you eat of the cake, the more you have left over.

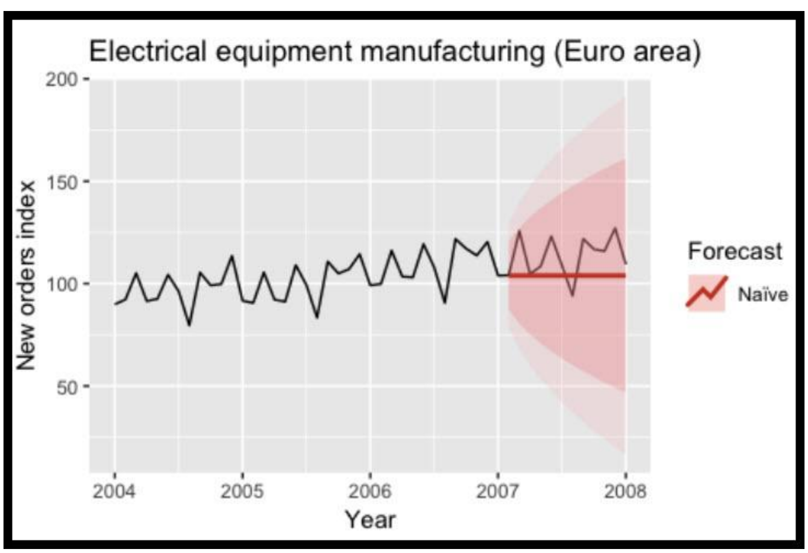
Now consider two categories of trash: wood and plastic. Let's say that they were the only two types of garbage found. If half the total garbage we find is wood, then plastic must also be half the garbage found. But is it possible that half of the garbage is wood if more than half of it is plastic? NO WAY! That's the same thing as eating more than the whole cake! Once all the cake is gone, you can't eat anymore!

Scatter-Plot (X-Y graph)



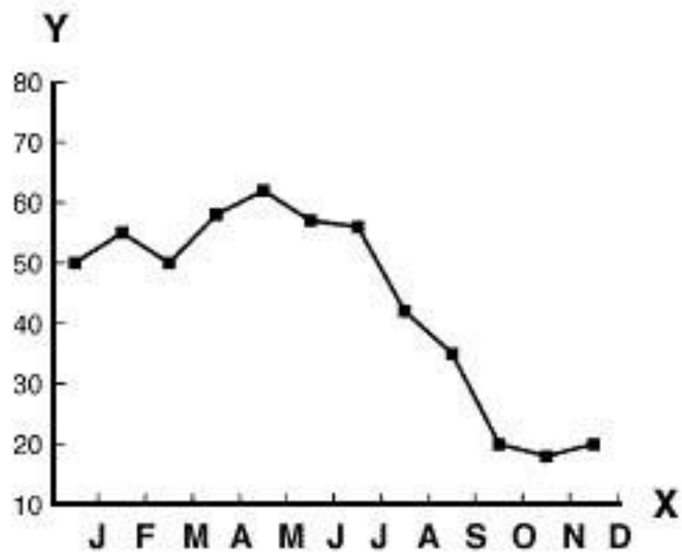
The scatter diagram graphs show numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line. (In Microsoft Excel, choose the "XY (scatter)" chart type, and then choose a sub-type that does not draw a line.)

Time-Series Plot



The time-series plot is an excellent way to visualize long sequences of data. It tells a visual story along the sequence axis, and the human brain is incredible at absorbing this high density of data, locating patterns in the data such as sinusoids, spikes, and outliers, and separating any noise from signal. (In Microsoft Excel, the "line graph" chart type generates a time series. By default, Excel simply puts a count on the x-axis. To generate a time series plot with your choice of x-axis units, make a separate data column that contains those units next to your dependent variable. Then choose the "XY (scatter)" chart type, with a sub-type that draws a line.)

X-Y Line Graph



How Does This One Variable Change Over Time?

A line graph shows the relationship between your dependent and independent variables when both are numerical and the dependent variable is a function of the independent variable. (In Microsoft Excel, choose the "XY (scatter)" chart type, and then choose a sub-type that does draw a line.)

What did I mean by “we need **consistent data**?” Well, line graphs suggest a trend through time, so we might get the wrong trend if we don’t have enough data.

Let’s say we took sightings on the number of whales in a given area, but only took them before and after they actually migrated through the area. Well, if we connected all the dots, then we would give a flat line of zero numbers through the time when they were not present. This gives the wrong trend, and the whales would be left out. You don't want to hurt their feelings, do you?

Here is a free site where you can visually communicate your data into charts and graphs http://nces.ed.gov/nceskids/createagraph/default.aspx. You have the option of selecting an area, bar, line, XY or pie graph.

You can turn survey data into charts here… https://www.displayr.com/

Example
You don't know if your solution is working unless you collect data. Don't get so involved in building and trying your invention or program that you forget to collect and record your data.

You may need to collect data to measure sound, distance, temperature, or effort (spring scale). Do a search in Google to see what measuring instrument you need.

Below is a simple table that was used for an invention project. The student wanted to find a solution for cutting down the echoing sound from student's talking in the school lunchroom. He used 30 seconds of tape and monitored the sound as it was reflected in a bare box and then each of the four types of panels. He recorded the sound and noted the highest decibel reading.

Type of covering	Trial 1	Trial 2	Trial 3	Average
Direct playback	71 db	71 db	71db	71 db
Bare box	68 db	69 db	67 db	68 db
Plywood	65 db	68 db	65 db	66 db
Smooth panel	68 db	69 db	70 db	69 db
Acoustic tile	50 db	48 db	49 db	49 db
Burlap fabric	45 db	47 db	44 db	45.3 db

Notice that the data organizes the results in an easy-to-read table. A table organizes data into **rows** and **columns**. Rows go across. Columns go up and down. Headings tell you what each column of data represents.

Now it is time to organize your table. Always give your table a title and label your rows and columns. You can use Excel or Word to create a table.

Recording Your Observations When Testing Your Prototype

It is not only important to take detailed notes and design excellent tables, it is also important to record your observations as you are building and testing your prototype in your Design Notebook. Keep your records in order of occurrence.

Record the following

- Thought-provoking incidences
- Challenges or problems that happen
- Anything you change to the step-by-step procedure – if you do something different than what you planned
- New ideas that you have
- The unpredictable that occurs

All the above will be the foundation of your Project Report which will include data, charts, graphs, conclusions and photos. You will be telling all in this report, including your accidents, failures and successes.

Be very precise when you record the procedure and measurements. Label your drawings. If you take pictures, write down the time, date and subject of the picture.

Whenever possible, remember to use numerical values when reporting data. If your project has qualitative data (not numbers), take photos or draw a picture of what happens at every step.

It is normal to find things that you want to change or adapt. It's all part of the process.

Helpful Tips

- Remember to document everything in your Design Notebook.
- The better observer you are the better your Project Report.

- The more details the better.
- Don't get sloppy as you move through the days testing your prototype. Neatly record <u>each step</u> in your Design Notebook.
- Sporadically, remind your family to stay away from your workspace.
- Keep supplies locked up or out of reach.
- Keep it clean and organized.
- Most importantly, be safe.

Tips on Recording Data

- Now it is time to **review and record the data** obtained from testing your design.
    - Include all your findings.
    - Collect more data when necessary.
    - Calculate everything correctly.
- Calculate an average for the different trials, if you did more than one trial.
- Label all tables so if a stranger is looking at them s/he will know what the chart is about. Include the units of measurement (grams, inches, volts, etc.).

Remember to record and keep everything in your Design Notebook.

Prototype Testing Outcomes Checklist

Print the checklist, fill it out, attach to your Design Notebook, and date your entry.

I Have an Excellent Science Fair Experiment Because…	✓
I recorded in detailed my observations in my Design Notebook and dated my entries.	
I recorded the data in a data table which I attached to my Design Notebook and dated my entries.	
I was careful and precise when I made my measurements.	
I recorded all changes I made to the experimental procedure (if any).	
I recorded all challenges or problems in my Design Notebook and dated my entries.	

Go on to the next section of this book if you checked off every single item above. If you didn't, then go back and complete the steps you missed.

Analyze Your Data

Evaluate Your Solutions

Letter "I" in the Timeline

An engineer evaluates all possible solutions. Ask yourself if things are working the way you want them to. What kind of revisions can you make? Analyze what works and what could be improved.

To find out if your invention worked or didn't work, look for patterns in the data. Analysis sometimes is seeing if the total weight, power of an engine or cost of materials meet the design requirements.

Use a table or other graphic organizer to help record and organize the data so it can be reviewed. These visual graphics will help you to see trends or compare before and after data.

Think of this step as, **Question Everything**. What worked well? Why didn't it work well? How could it be improved? These questions most often are going to send you back several steps. Discuss how you could improve your solution.

It is important to state whether or not you met your design criteria.

Use Calculations to Analyze Your Data

When indicated, use a spreadsheet, like Microsoft Excel, to perform calculations on your raw data. The results will help you to form your conclusions. You can use the spreadsheet to show the results in your Project Report. Remember to label the rows and columns.

Remember to keep all the units of measurement consistent. For example, L with L, mL with mL. Here is an extensive list of symbols: http://whatis.techtarget.com/reference/Table-of-Physical-Units

Draw Conclusions

Letter "I" on the Timeline

This is the brutally honest section where you assess the strengths and weaknesses of your design, and its state of readiness for production. Be enthusiastic, but candid. Do not oversell or undersell your solution. (Recommendation: avoid using "I/we ran out of time" as a theme in this section or anywhere in the report.)

Take out your Design Notebook, using your notes and charts, analyze what happened as a result of your testing.

Your conclusions are a summary. It states whether or not you meet the objective (to design a good solution and respond to the original needs statement). It needs to be clear, concise and to the point. Resist the temptation to give your own interpretation or opinion. Simply stated, it tells whether the results of your science fair project accomplished what you wanted it to.

The conclusion must be based on your evaluation, because presumably, a design that meets the requirements is a good design. However, the results often are different than what you expected, things are learned along the way and there is never enough time to perfect the solution.

You can include a specifications table, showing all specification requirements vs. actual values for the final design. Address the true value of your design. Make sure to highlight the unique features you have added to your design.

Also remember to include the following information:

- If your design is going to have an effect on the environment, it needs to be evaluated for total environmental impact, including concerns related to energy use, emissions, and total life cycle issues (environmental impacts of production methods [hazardous materials?] and product retirement [longevity and recyclability])

- Clearly state whether or not you believe it is a good idea to continue or cancel the project, based on your understanding of the market, the production costs, and the overall impact that producing this design is likely to have relative to addressing the original needs statement. Justify your recommendation.

- If you believe that your project needs to be continued but is not ready for production, clearly state (in specific actions, not generalities) what needs to be done to reach the "production-ready" state, and attempt to place a schedule and budget on the remaining work.

If your results did not solve a problem or meet a need do not go back and make changes in the hope that you will come up with a different result. All you have to do is provide an explanation of why your prototype did not conform to your expectations. This is part of the design process. And realize that you have already made big strides in your scientific knowledge.

Actually, professional engineers welcome unexpected results. They use them to construct another prototype. Science fair Judges care only about what you have learned, not whether you have found a solution.

If you were not able to solve the problem, think about the questions that occur to you at this point, and what additional changes could be made.

Use your Design Notebook to jot down ideas and thoughts about the conclusions drawn. Write your conclusion in your Design Notebook.

Data Analysis Outcomes Checklist

Print this page, fill out each checklist, attach to your Design Notebook, and date your entry.

Check off all the outcomes you accomplished	✓
I developed a test plan and have attached it to this checklist.	
I used ________________________________ measuring instrument to collect data.	
If people are involved in the testing: I had SRC (Scientific Review Committee) approve the testing before I proceeded to test.	
I included the target users in the testing.	
I used at least 3 users to test the solution in the environment where the problem occurs.	
I observed the target users when they were testing the solution and recorded my observations in my Design Notebook.	
I collected enough data to test my design to see if it meets the criteria and constraints.	

Only move on to the next checklist if you were able to check off each above statement.

Graph Outcomes Checklist

Check off all the outcomes you accomplished	✓
I used the correct type of graph to express the data.	
I gave each graph a title.	
I labeled the axes correctly and specified the units of measurement.	
The graph has the appropriate high and low values on the axes.	
I plotted the data correctly and clearly.	

Only move on to the next checklist if you were able to check off each above statement.

Drawing Conclusions Outcomes Checklist

Check off all the outcomes you accomplished	✓
I was brutally honest in writing my conclusion.	
I looked for patterns in the data to determine if my invention worked.	
My design solution meets the original design criteria.	
I went back to the problem statement and am sure that the solution solves the problem. If not, I stated whether or not the project should continue or be cancelled.	
I summarized the results and used it to support the findings.	
I stated what worked, what didn't work, why it didn't work and how it could be improved.	
I had to refine, redesign and retest ______________ times until the prototype worked according to the design criteria.	

Only move forward to the next section after you were able to check off all the statements.

Step 7. Refine, Redesign and Retest as Needed

Letter "H" on the Timeline

Some Engineering Design Process steps place this section as Step 8 and Step 7 as the Communication section. Because most prototypes are refined or redesigned, I thought it important to have this section before the Communication section.

If you find that your prototype is not working or that there are deficiencies in your design, then you will have to go back to Step 4 and redesign or design a new solution, then build it, and then test again. The more you redesign and retest, the more extensive will be your data.

Sometimes just changing one thing like the size of a screw improves your prototype so that it meets the design requirements. And sometimes you have to start all over from the beginning. You are either going to have to fix a problem or improve your design so that it works better than you had hoped.

There is nothing wrong with you if this happens. It is the norm. So, take a deep breath and proceed on your adventure!

Willis Carrier, the inventor of modern air conditioning, tested his prototype for years before it worked the way he wanted it to <u>and</u> solved the problem he wanted to fix. It's OK to fail a lot, because each time you fail you make your product better in the end.

When you retest the redesigned prototype, ask the same questions that you did when you tested the first one:

- What do they like?
- What do they dislike?
- Where could you make changes for the better?
- Did the user overcome their problem with your solution?
- Did the user have to ask questions to clarify certain steps?
- Where in the interaction did the user ask questions?
- What were their questions?
- Did you meet your measurable targets?
- Did the solution work the way you wanted it to?

Every time you get a “no” answer, that means you have to go back and refine or redesign again. Then follow the same process you did to test the previous prototype. Keep on repeating the same process until you have a solution that meets your criteria. You may get frustrated, but each time you refine or redesign you are improving your solution and getting closer to having a working solution.

Tips for Retesting

- Examine and evaluate your prototypes or designs based on the criteria and constraints. Be sure to prepare an analysis of what went wrong and how you will fix it. You can go through this process up to six times or more!

- Groups may enlist students from other groups to review the solution and help identify changes that need to be made. If you are working on a design by yourself, ask other students to review your model. Ask the reviewers to identify any problems and proposed solutions.

Step 8. Communicate the Results / Design

Writing Your Project Report Paper
Letter "G" on the Timeline

Overview
The designer's real product is the description of a design from which others will build the product. Use your Design Notebook and the science fair exhibit to communicate the design to your customer and the Judges.

What is a Science Fair Project Report Paper?

- A summary that answers the research question you wrote when you did your background research.

- A review all of your references you consulted in searching for those answers including written publications, Internet resources, and interviews with experts.

- A way to impress the judges by showing them how well you understand the results of and the theory behind your experiment.

- A communication to others that details what you did and possible research that they can do to improve upon your findings. It is the write-up of your research and design process.

There are 3 steps to finishing your science fair report:

Step 1. What is the most efficient way to write your paper?

Use your Timeline because it will give you an easy outline to follow. It shows you from beginning to end every step you took to complete your project investigation.

Your Design Notebook will fill in all the details, including the data expressed in words, charts and tables.

Step 2. This is where you write your science report with all the gory details!

But you say, "I'm not good at writing". Or, "I can't stand to write papers." Believe it or not, I use to freeze every time I had to look at a computer or paper to write even a sentence.

SECRET FILES #7

Don't worry about it. Just write whatever you know... after all, you ran the investigation and you were there every step of the way!

Keep in mind that your report needs to include every minute detail of your investigation so that your design process can be duplicated. If someone read your report and knew nothing about the project, they would be able to experience all the details of your investigation as if they did it themselves.

After you write the report, go back and fix it up. And remember to have someone edit your report... more on that later.

Step 3. Once your report is written it is time to write an abstract.

What is an abstract? It is a brief, written discussion of your science fair project. We will later discuss what sections to include and how to write one.

So, let's move on to writing your science fair project report...

SECRET FILES #8

Tips for Your Project Report

This time you are writing the details of your report. Would you believe that you are getting down to the wire of bringing this project to a close?

Do you know the saying…? *If you think you can, you can.*

And if you think you can't, you're right!

Mary Kay Ash, Founder of Mary Kay Cosmetics

Well, I think – you think – you can because you have. And that's what counts the most… what YOU feel, think and believe.

Enough chatter. Let's move on…..

Before you write your report, check with your teacher regarding your school's rules and guidelines. It precedes anything we recommend.

1. Your report will most likely be long. Chunk this section into bite-size pieces, doing a little bit every day. It may take you up to a week or two to complete the whole report. Using a word processor makes it much easier than writing it by hand.

2. Check your ink cartridges. Make sure that they are full. You will want to use various colors to make your charts, tables and graphs. If you need to replenish your supply, now is the time to purchase them.

3. About every 5 minutes save your document. You don't want any of your work to be lost if all of a sudden there is a glitch with your computer. At the end of the day make a copy of your document in case one gets corrupted. Time is precious and you don't want to waste it.

4. Use spell and grammar check at the end of every day. As you finish a day's work, print it out and read it. Make any changes on the paper. Then give it to one of your parents or older siblings and ask them to write suggestions in the margin. The next day, input your changes before you begin writing the new material.

Organization and Sections of Your Project Report

- The Title Page – page 1 of your report. In the center of the page write the Project Title, your name, grade, school and date. Some schools want only the Title of your project on the first page. Write the title so it grabs the reader's attention. Do not make it the same as your Big Question.

- Table of contents - page 2 of your report. Include a page number in front of the name of each section. Center the word "Content" or "Table of Contents" at the top of the page. Number the sections of the report in a list below the Table of Contents. If you know how to make a Table of Contents (TOC) automatically generated, that is the most accurate way to format the TOC.

  Table of Contents

  1. Abstract
  2. Introduction
  3. Define Problem or Need
     - Problem Statement
  4. Background Research
  5. Design Statement and Criteria
     - Design Brief
  6. Designs
     - Beginning Designs
     - Final Prototype Designs
  7. Materials List
  8. Step-by-Step Procedure
  9. Build & Test a Prototype
     - Retest and Redesign If Necessary
  10. Data & Conclusions
  11. Communicate the Results / Design
  12. Ideas for Future Designs
  13. Acknowledgements
  14. Bibliography

- Abstract - a brief overview of the project - one or two paragraphs. No more than one page. Write the Abstract last because then you will have an overview of what your project was about.

- Introduction - explanation of what prompted your research and what you hoped to achieve. In other words, what is the purpose of your project.

- Defining the Problem or Need - the Problem Statement is answered by the results of your project.

- Background Research - this is the research paper you wrote before you did your prototype.

- Materials List - lists all the materials and supplies you used for your design.

- Design Procedure - describe in detail the method used to collect your data or make your observations. Be sure to explain every detail so that someone could repeat the project procedure step by step. This is where you include your photos.

- Data Analysis & Discussion - include all data and measurements from your testing along with drawings and tables. The discussion explains the results and is a summary of what you discovered during your observations, from your data table(s).

  If you have extensive data that is several pages, put it in an appendix at the back of your notebook. If it is very long put it in another binder, write a summary statement along with the data.

- Conclusion – results and conclusion obtained from doing your design process.

  - Compare your results with published data you found in your research.

  - Possible ways in which the project could be expanded or improve upon.

  - Suggest an alternative solution to solve your "problem" if you could not solve the problem or meet the need.

  - Only include what was stated earlier in the paper.

- Ideas for Future Research - Some schools want to know what you would do differently if you repeated the process or possible ways in which the project could be expanded in the future.

- Acknowledgements - brief statement stating the names of people who helped you and thanking them for their contribution to your success.

- Bibliography - Books, magazines, journal, articles, Internet websites, interviews that you used to do your research. Ask each person's permission that you interviewed to print their name, title, work address and work phone number. Be sure that each source you cite in your paper appears in your bibliography.

- Your product description will be conveyed in drawings, photos, material list, assembly instructions, test plans and results. Consider listing lessons learned so future designers need not repeat any of your “frustrations or failures.” Have clear instructions on how to produce your design, along with production cost estimates.

Formatting Your Paper

Remember we discussed MLA and APA guidelines in the Bibliography? Ask your teacher what format she wants you to follow and if she wants to change any of the formatting guidelines as listed below. Show her this list.

	APA Guidelines	MLA Guidelines
Paper		8.5" x 11" (standard size in U.S.
Page Margins	1" (top, bottom left, right)	1" (top, bottom left, right)
Font Size	12 pt. Times Roman or Courier. Figures: Arial	12 pt. (Times, Roman, Arial, Calibri)
Line Spacing	Double-spaced	Double-spaced (include captions and bibliography)
Alignment of Text	Flush left with an uneven right margin	Flush left with an uneven right margin
Paragraph Indentation	5 to 7 spaces	½" (or 5 spaces)
End of Sentence	Leave 1 line space after a paragraph unless your teacher wants 2 spaces.	Leave 1 line space after a paragraph unless your teacher wants two.
Page Numbers	On all pages, ½" (except Figures) from top of right margin and flush with the right margin, 2 or 3 words of the paper's title (called the running head) and 5 spaces to the left of the page number, beginning with the Title Page. Example: Student's Guide to 1	On all pages, ½" from top of right margin and flush with the right margin. Put your last name followed by the number. Example: Binder 1
Title Page	The Title Page is the 1st page of your report. The running head is flush left in all upper-case letters, following the words, "Running Head". Example: `Running Head: TITLE OF YOUR PAPER` Below the running head, center the following on their own lines, using	On the 1st page in the upper left corner, on separate lines, double-spaced: • Your Name • Teacher's Name • Course Name or Number • Date Underneath, center the title of your Project Report using regular title

<table>
<tr><td></td><td>upper- and lower-case letters:
Paper Title
Your Name
Your school</td><td>capitalization rules and no underline.</td></tr>
<tr><td>Section Headings</td><td>On the page center Level 1 headings, using upper- and lower-case letters.

Place Level 2 headings flush left, italicized, using upper- and lower-case letters.
Example:

Communicating Results (Level 1)
Writing Your Final Report (Level 2)</td><td></td></tr>
<tr><td>Tables, Diagraphs, Illustrations and Photos</td><td>Place tables and Illustrations at the end of your paper.

Each table is placed on a separate piece of paper, typed flush left on the 1st line below the page number.

Double-space the table title flush left (italicize the letters using uppercase and lowercase letters). Example:
Table 1

Place figure captions on the last numbered page of the report. The label figure is italicized and the caption is not. The caption uses regular sentence capitalization. The figures follow, one per page.</td><td>Sources and notes appear below the table, illustration or photo, flush left.

Label the table, Table. Number the tables in numerical order: Table 1
Place the table label and caption above the table, Capitalize like a title, flush left.

Photos, illustrations, charges, graphs or diagrams are labeled Figure or Fig., labeled in numerical order:
Fig. 1

The label, title and source (when there is one) is placed beneath the figure, flush left, in a continuous block of text, not on a separate line:</td></tr>
</table>

Order of Major Sections	Each section begins on a new page: • Title Page • Abstract • Body • References • Appendixes • Footnotes • Tables • Figure Captions • Figures	
Binding		Ask your teacher what s/he prefers. (staple, paper clip or placed in a 3-ring binder)

First Draft

Your report is the written expression of all your work.

Letter "G" on Your Timeline

- Write a first draft of your Report. A first draft is the first time you write your report. Include the following:

    Abstract (write after finish everything below)
    Introduction
    Define Problem or Need
    - Problem Statement

    Background Research
    Design Statement and Criteria
    - Design Brief

    Designs
    - Beginning designs
    - Final prototype designs

    Materials List
    Numbered step-by-step of your procedure
    Build & Test a Prototype
    - Retest and Redesign If Necessary

    Data & Conclusions
    Communicate the Results / Design
    Ideas for Future Designs
    Acknowledgements
    Bibliography

- When possible, use a computer to write your report. Double space your lines.

- Create data charts, graphs, tables and pictures. Use the spell check to edit and revise your report.

- You are going to want to reference your sources of information and quotes. Go to https://www.youtube.com and do a search: how to input footnotes in a word document.

- Ask someone who has excellent writing skills to edit for grammar, clarity and spelling.

- **Letter "F" on the Timeline:** After the 1st draft is edited, input suggested changes. Give this 2nd draft to the editor to proofread the paper again.

Final Copy
Letter "E" on Your Timeline

When you are satisfied with the results, type a revised, polished copy for your final report. Be sure to spell check this final copy.

- Print your final copy, on only one side of the paper, on clean white paper.

- Place each sheet of paper in a 3-ring, clear protector (see Shopping List 2).

- Then put all the protected papers of your report in a 3-ring notebook that has a pocket. (see Shopping List 2) This notebook will be handed in to your teacher and placed on your display table at the science fair.

Project Report Outcomes Checklist #1

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

Once you have finished writing your Project Report, put it aside for a few hours or even a day if you can. You want to read it again with "fresh eyes". Any deficiencies will become clear to you based on these criteria:

I Did an Excellent Project Report Paper Because....	✓
I defined all important terms.	
I answered all my research questions.	
My background research helped me to write a design statement / criteria.	
I have included math that helped me to interpret my data.	
Credit was given to all the sources that I used. All copied phrases, sentences or paragraphs are in quotations.	
I recorded in my Design Notebook the experts that I interviewed and what I learned from each interview.	

Do not stop working on this section until you can truthfully check off the above statements.

Writing Your Abstract

What is a Science Fair Project Abstract?

Letter "D" on the Timeline

Overview

The purpose of an abstract is to give the reader an overview of your project so that s/he can decide whether or not to read the entire report. Get the reader excited and motivated to read your Abstract.

- An abstract is a brief, written discussion of your project.

- Each abstract consists of a brief statement of the essential, or most important, thoughts about your project. Abstracts summarize, clearly and simply, the main points of the design process and/or the main sections of the report. Syntax, spelling, grammar, punctuation, neatness, and originality are important.

- Each student who does a science fair project must write an abstract that will be displayed with their project.

- Some science fair project abstracts are placed on the table in a folder while others are attached to the display board. Follow your school's guidelines.

- Think of your abstract as the “coming attractions” for a movie. If your abstract is interesting enough, people will be excited to read your final project report.

Details

Explaining your project in an abstract of 250 words can be a challenge, and many students actually find it easier to write the long final report. Yet, the abstract is a critical part of your science fair project.

It appears at the beginning of your final report, and also on the display board or table at the science fair. It's a summary that tells the reader what your project is all about.

5 Sections of Your Abstract

0. Project title
1. Purpose of your project
2. Problem Statement
3. Description of the procedure
4. Results
5. Conclusions

It may also include any possible research applications.

Write a very brief explanation of each:

1. **Introduction - Purpose of Your Project**
   Why You Undertook the Project
   - Something motivated you to invent a better way of doing something. Was it an observation you made, a question that occurred to you, a frustration you experienced with some aspect of daily life? Let the reader into your head.

Write an introductory statement of the reason for investigating the topic of your project.

- **A Statement of the Problem**
  A single clear statement is all that's needed. State what problem you wanted to solve.

2. **Procedures Used - What You Did**
   - Overview / summary of the step-by-step procedure in designing your solution.
   - Only include procedures that you, the student, did.
   - Do not include work done by a mentor, acknowledgements, work done by a university lab or work done prior to your involvement in your project.
   - Do not give details about the materials used unless it greatly influenced the procedure or had to be developed to do the investigation.

3. **Observation/Data/Results - What You Discovered**
   - State the key results that led directly to the conclusions you have drawn. What contribution did you make in completing this project? Were your objectives or design criteria met?
   - Do not give too many details about the results nor include tables or graphs.

4. **Conclusions - What It Means?**
   - Describe briefly conclusions that you derived from your investigation.
   - In the summary paragraph, reflect on the process and possibly state some applications and extensions of the investigation.

Abstract Template

Do not use bullet points in your abstract. They are written below to give you directions. Remember you only have 250 words, which does not include the Title, Your Name or School Name.

The colors in the abstract example demonstrates the following concepts. Do not use the colors in your Abstract:

Title Name School
Purpose of Project (green) ◦ An introductory statement of the reason for investigating the topic of the project. ◦ Write your Design Problem ◦ A statement about the problem or need you want to solve.
Procedures Used (blue) Summarize procedures, emphasizing the key points of steps. ◦ A summarization of the key points and an overview of how the investigation was conducted. ◦ Omit details about the materials used unless it greatly influenced the procedure or had to be developed to do the investigation. ◦ An abstract must only include procedures done by the student. Work done by a mentor or work done prior to student involvement must not be included.
Observations/Data/Results (red) Very briefly detail observations / data / results. ◦ Only write the key results that lead directly to the conclusions you have drawn. ◦ Don't give too many details about the results nor include graphs or charts.
Conclusions (pink) ◦ State conclusions / applications. ◦ The summary paragraph must only reflect on the process and possibly state some applications and extensions of the investigation. ◦ An abstract does not include a bibliography unless specifically required by your local fair. The Intel ISEF requires the bibliography as part of the research plan to be provided on Form 1A.

(Cole, Mastering the Writing Process)

Sample Abstract

A detailed comparison of the properties and microstructures of conventionally sintered and microwave sintered samples of 3 mol% and 8 mol% yttria zirconia was performed.	Aim of the research
Identical thermal profiles were used for both types of heating.	Method
For both materials, microwave heating was found to enhance the densification processes which occur during constant rate heating.	Summary of overall results
The 3 mol% yttria zirconia material exhibited a shift in the grain size/density relationship which favours densification, resulting in higher density samples with smaller grain sizes at densities below 96% of theoretical density. At higher densities, significant grain growth occurs.	Detailed result for one of the experiment's samples
For the 8 mol% yttria zirconia material, the grain size / density relationship remained unchanged. Differences in the response of the two materials are attributed to the differences in the activation energy for grain growth, and in grain boundary mobility.	Detailed result for the other of the experiment's samples
Modulus of rupture and toughness of both microwave and conventionally sintered samples were similar. Following isothermal heating at 13000C, microwave heated samples were found to be significantly more dense than conventionally heated samples. This temperature also restricted grain growth once densification was approaching completion.	Further results (comparison of two methods of sintering)
These findings have significant implications for the commercial application of microwave sintering. It appears that this method of sintering produces a superior product to conventional sintering.	Significance of the results

Writing & Revising Tips

- The abstract is printed on one page and is usually between 100 to 250 words long for grades 4 through 12, and between 50 to 250 for grades 3. (check with your school for their guidelines)

- **Revise and edit the abstract in the template**. To write only 250 words, first write a draft of the abstract. Then go back and cross out all extraneous words, phrases and sentences. Combine sentences together. Take a break and go over the abstract a couple hours later or the next day. The finished abstract will only be the “bare bones” of your report.

- Include the Project Title, School Name, City, State and Grade Level.

- To keep to the 250-word limit, each of these points needs to be covered in only a sentence or two. However, in your first draft, just write down your thoughts without worrying about the word count. Your second (or third, or fourth!) draft is for strengthening your sentences and improving word choices.

    - Focus on these points: purpose (problem statement), methods, scope, results, conclusions, and recommendations.

    - Do not include any mentor or supervisor’s work.

    - Leave out details and discussions.

    - Combine sentences and/or paragraphs. You will probably edit several times in order to shorten the sentences.

        - Delete words, phrases or sentences that do not add anything to what you’ve already stated.

        - Use short sentences but still vary the structure.

        - Eliminate jargon.

    - Write in the past tense, but when necessary, use active verbs rather than passive verbs. Examples:
        - Active verbs: clarified, reviewed, inspected
        - Passive verbs: is, was, has been
    - Use complete sentences. Do not abbreviate words or leave out small words.
    - Spell check for spelling grammar and punctuation.
    - Eliminate words that are too technical for most readers, but still use scientific language when necessary.
- <u>Do not include</u> tables and graphs.
- Judges and the public must have an accurate idea of the project after reading the abstract. Yet, you want to grab the reader's interest because it will influence their attitude about your full Project Report when they review it.

  Look at it like a trailer to a movie. Make it interesting and engaging. To do this you will probably have to do more than a couple of drafts. Have other's read it and give suggestions each time to revise your draft.
- Focus only on the current year's research. Give only minimal reference to previous work.
- Do not include details and discussions in the abstract, but they may be put in the longer, written Project Report paper (if required), or placed on the display board.
- An abstract does not include a bibliography or citations unless specifically required by your local fair.
- The Intel ISEF requires the bibliography to be part of the research plan.
- <u>Neatly</u> fill out the science fair form that your school gave to you.

Abstract Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

I Included....	✓
A sentence or two introducing the reason for your project	
A statement of the problem	
The procedures you used	
The results you obtained	
The conclusions you drew	

I Eliminated....	✓
Terms that are too technical	
Jargon	
Unexplained acronyms	
Unnecessary repetition	
Bibliography or citations	
Tables or graphs	
Procedures done by scientist or mentor	

Do not go onto the next page until you can check off every single item above.

Project Report Outcomes Checklists #2

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

I Included....	✓
Abstract I wrote a summary paragraph on each of the following sections: o Problem Statement o Procedures o Results - I discussed whether or not I met my design criteria. o Conclusions	
Final Report I included in my final report all the following sections: o Title Page o Abstract o Table of Contents o Problem Statement o Background Research o Design Requirements – Design Brief o Requirements & Criteria o Proposed Solution o Materials & Supply List o Procedure o Final Design o Results (include data, tables and other charts) o Conclusions o Idea for Future Research o Acknowledgments o Bibliography	

I did the following.....	✓
I had someone other than myself edit my report (including Abstract).	
I typed / input the final copies of both abstract and report.	
I printed both the abstract and report using a computer printer or going to a quick print store?	
I placed each of the pages of the report in a 3-ring clear plastic protector.	
I placed all the protected sheets of the report in a 3-ring binder that matches one of the colors of my display board.	

Please, do not move on to the next section of this book until you have completed everything on the list that your school requires. Hang in there! You are in the home stretch!!!

Take a long-needed break. See you tomorrow when you begin doing your display board. Make sure you have all the necessary materials. If you like doing art and craft projects, you will have lots of fun.

Display Board

Letter “C” on Your Timeline

Overview

Did you know that your display board is the first impression that the Judges see? It is a display that tells the story of all your efforts. Keep it simple, very neat and well organized.

- Rules are different for each school regarding sizes, shapes and material composition for the backboards / display boards / exhibit boards. Check with your school before purchasing materials.

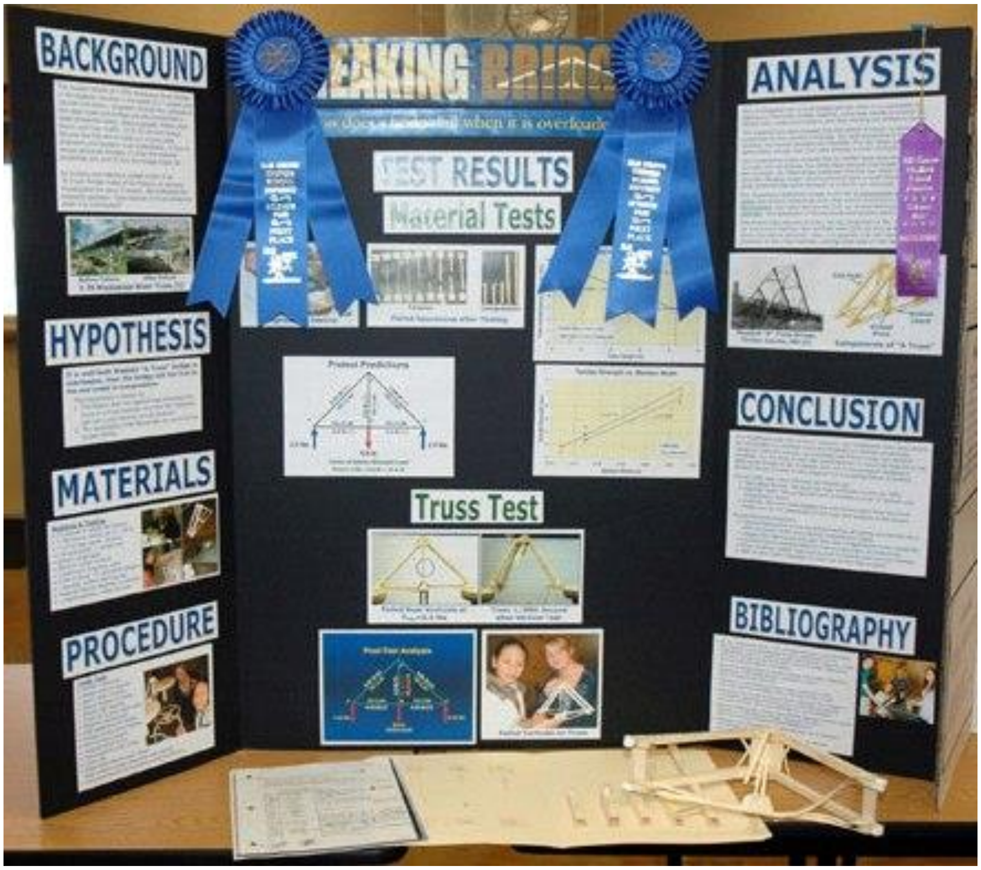
Color Scheme

- Before you purchase anything for your display board, decide on a color scheme. Do a search on the Internet on “how to use a color wheel”. This will help you to choose your color scheme. It is best to not use more than three to five contrasting colors. Check to see your school’s rules.

  1. A color for the background
  2. A color used to frame your papers – same color for border if you have one
  3. Ink used for the story of your report (black is easy to read).

- Do not use neon colored display boards or lettering. It takes away from the display and does not look professional. Also, the light in the science fair room causes a glare that reflects off the letters, making them difficult to read.

We could only find one display board that was designed for an engineering science fair, but the design principles are the same whether you are doing an experiment or designing a prototype. Notice that it is simple, neat, well organized and invites a person to visit and learn more. And isn't that what you want? For the Judges to be attracted like a magnet to your project!



Notice that the board lists a hypothesis. An Engineering Science Fair Project does not have a hypothesis. This is a mistake that can be seen all over the Internet. Do not make the same mistake.

Use your creativity. Envision in your mind how you want your board to look. On a piece of paper sketch a design that is in balance and flows - as illustrated in the above example.

Make copies of your sketch. Use crayons or colored pencils to try out different color combinations.

Materials

- For supplies, look at **Shopping List 2**.

- Before attaching anything permanently to the display board, arrange and lay the border (if you have one), titles, sections of your project report, charts and tables, photos, and illustrations in a neat and logical order.

Display Boards

- A display board is made up of sturdy material, has 3 panels that folds out so that the board can stand up by itself. Most schools want you to use the standard size tri-fold display board, which is 36" tall x 48" wide. These boards come pre-made in 1-ply, 2-ply or foam and can be purchased at your local teacher's store, Wal-Mart, Michaels, Joann Fabrics or at Amazon.com. They are inexpensive and can be purchased in different colors.

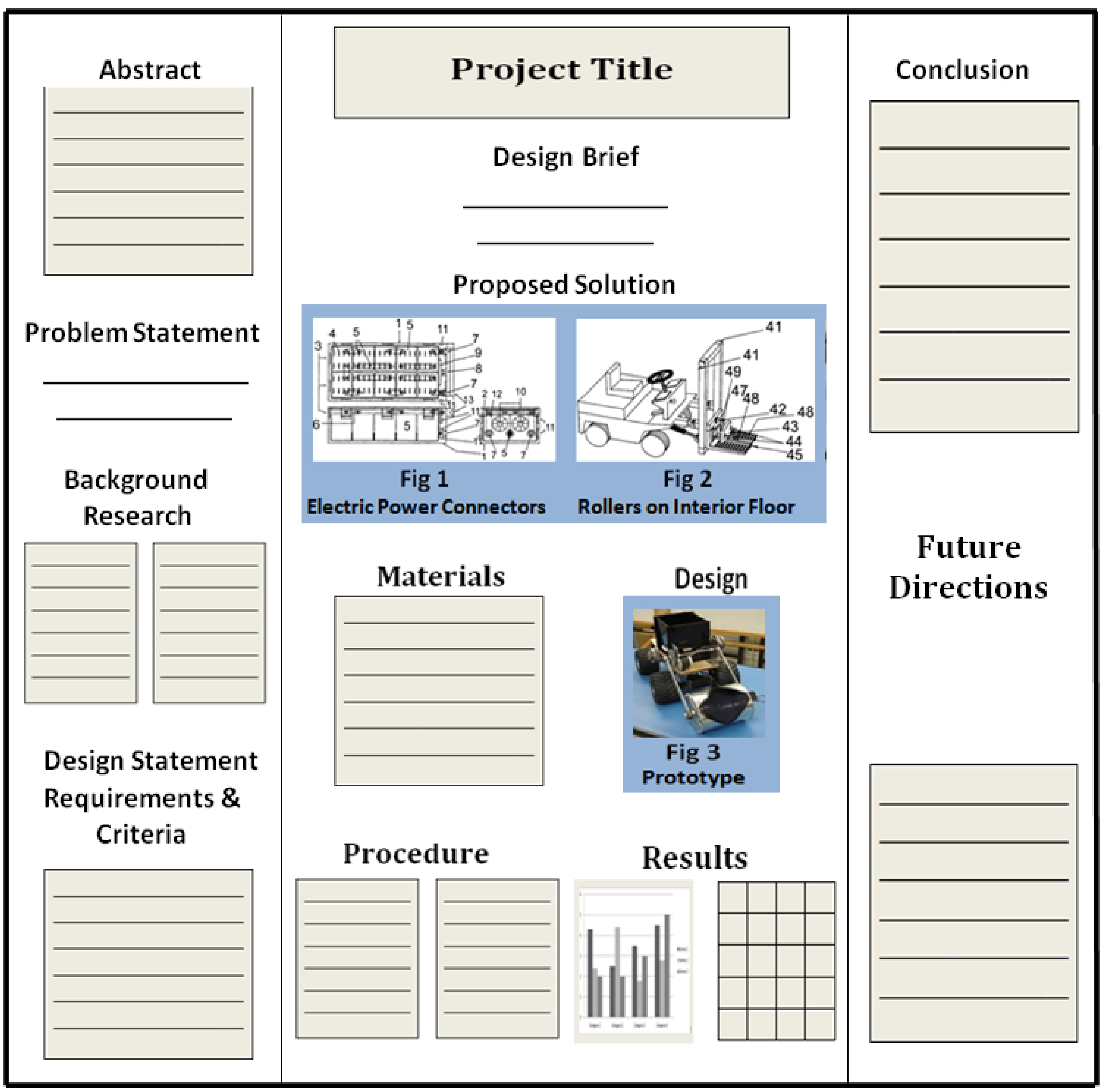
- We do not recommend making your own display board because it is time consuming and will never look as professional as the store-bought ones.

  - Use a black color Sharpie Permanent Fine Point Marker. On the back of the display board, list your name, school name, grade and science teacher's name.

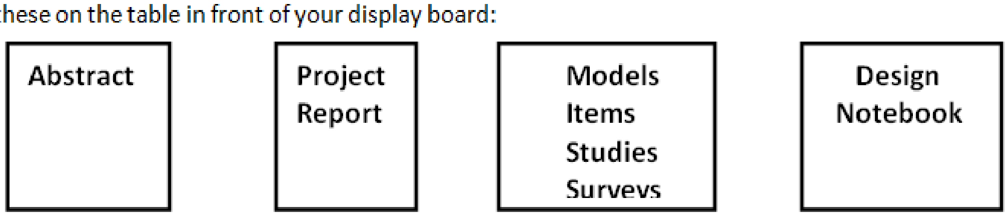
  - Use a glue stick or rubber cement to attach your sheets of paper to the display board. Double-sided tape works well for attaching photos.

How to Arrange Your Display Board

Arrange the display board like a newspaper so that the viewer can read from top to bottom, left to right. Include each step of your project in this order: Abstract, Problem Statement, Background Research, Design Brief, Problem Statement, Requirements & Criteria, Design Brief, Proposed Solution, Materials, Testing, Design, Results, Conclusion, Future Directions.



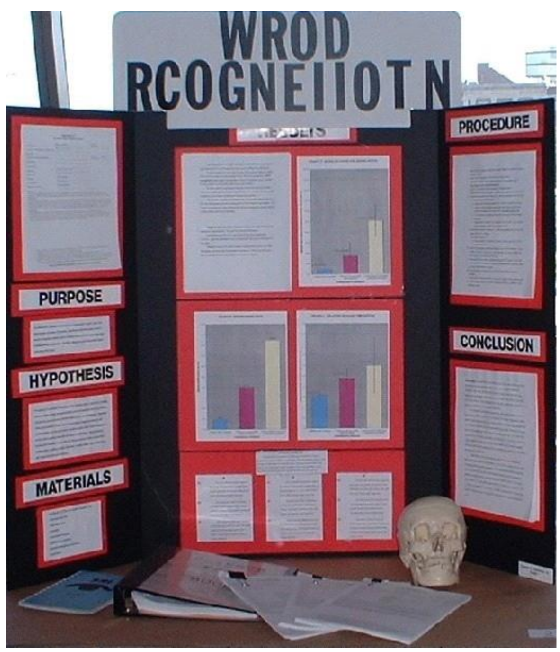
Place these on the table in front of your display board:



Header

A header sits on top of the display board and inserts into the 1st and 3rd panel.

- It makes the display board sturdier.
- It provides extra space for the Project Title.
- It grabs the viewer's attention.



Project Title, Subtitles & Captions

Project Title

The Project Title is a shortened version of the conclusion in your project paper. Grab the audience’s attention by writing an interesting Project Title.

Lettering Sizes on Display Board

- Make the Title letters larger than the subtitles – 150+ pt, at least 2” tall. It needs to be visible from across the room.

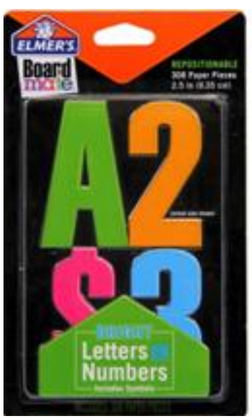
- Make the headings 32+ pt. It needs to be visible 5 feet away.

- Make the subheadings 20+ pt. or at least 1” tall.

- Make the Captions 12 – 16 pt.

More Tips

- Make your Title Headings look professional. Large repositionable and stencil letters are a good alternative to printed text. They are available at Amazon, a teacher's store or an office supply store.



Letters & Numbers

Stencils

Markers

Jumbo letters 4” high

- You can design the letterheads on a computer. If your printer does not print sharp looking images, email a pdf file to your local print shop. They can make copies using color cardboard stock.

- Place the title at the top of the middle panel or on a header.

- Use a darker color for the title and subtitles such as dark blue, royal blue, medium green and purple.

- Lighter colors can be used such as light blue, yellow, light green as a background for the letters, but it really isn't necessary if you have a white display board.

Subheadings / Headlines

Display photographs, illustrations, drawings, charts and tables underneath subheadings.

Pages on Display

- **Fonts**
  - Use a font size of 16 pt for the text on your display board.

  - Use font style Arial, Times New Roman or Calibri

  - Use *italics* or bold only for emphasis. Do not use either of them for all the text.

  - Don't use script or artistic fonts because it is too hard to read.

  - Do not place any text on top of a picture because it is difficult to read.

  - Don't use all CAPS because it makes it very hard to read.

  - Do not use white letters with a black or dark background because it is too difficult to read.

  - Do not use more than 2 or 3 different font styles on your board.

- Type and print the report pages that are going to be displayed on the display board. Make the print large enough so that a person standing in front of your table can read it without squinting or leaning forward to see.

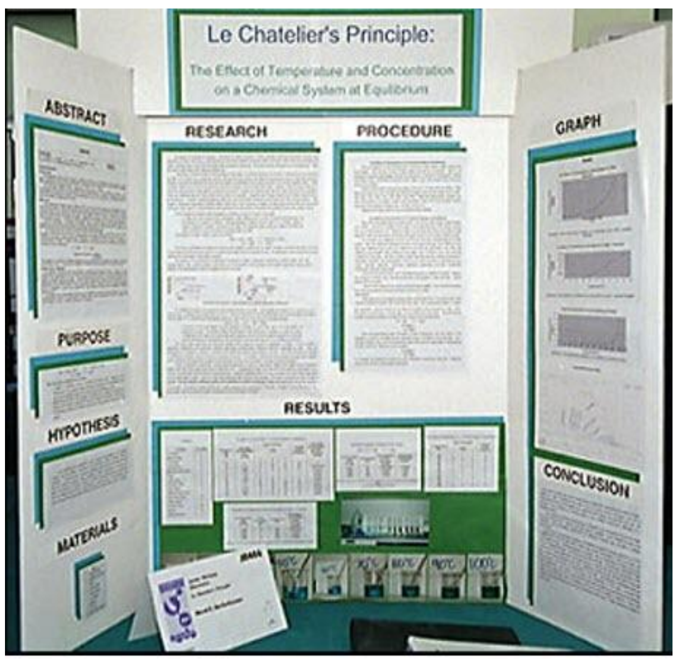
- Border around the report pages

- The border needs to be one of the 3 to 5 contrasting colors from your color scheme. This will make your pages stand out, especially if you have a white or light color display board background. Colored construction paper comes in 9” x 12” or 18” x 24” with many color choices.

- An easy way of creating a border is to put sheets of construction paper behind the white paper containing the sections of your Project Report. Choose a color that matches the title letters.

- Don’t put different colors under each section of paper. It will make the board look chaotic.

- If you have to buy large sheets of construction paper, cut them to size using a paper cutter because it makes a more professional looking edge. Use a ruler and pencil on the wrong side of the paper. Lightly mark the outer margins where you will cut. Use a paper cutter at school or at your local print shop.



- Computer generated tables, graphs and charts look best. If you draw them by hand, make your drawings neat. Use colored pencils to accent the varying results.

- If possible, have a focal point from which the other pages, tables, graphs, charts and photos stem. This will create continuity and flow.

- Number each graph or image and put them in numerical order.

- Have a caption under each graph, illustration and photo. Format it to fit the length of the image. Print the caption on white paper. The caption needs to be placed within the colored frame. Look at the following example.

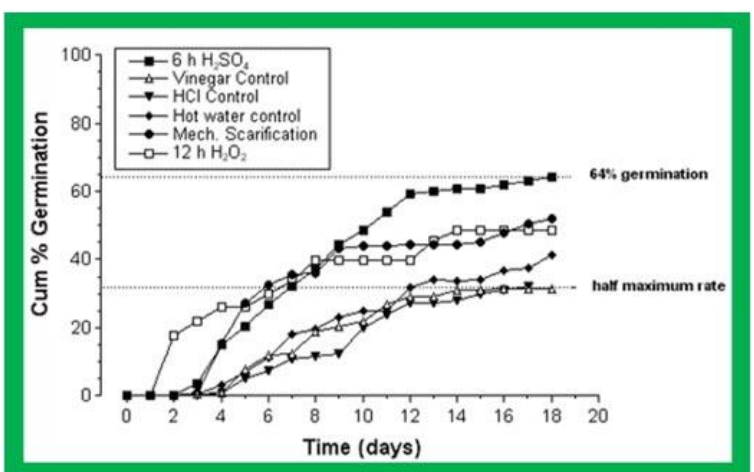


Figure 2. Cumulative germination of gourd seeds following various pregermination treatments. n = 100 seeds per trial.

Border for the Display Board

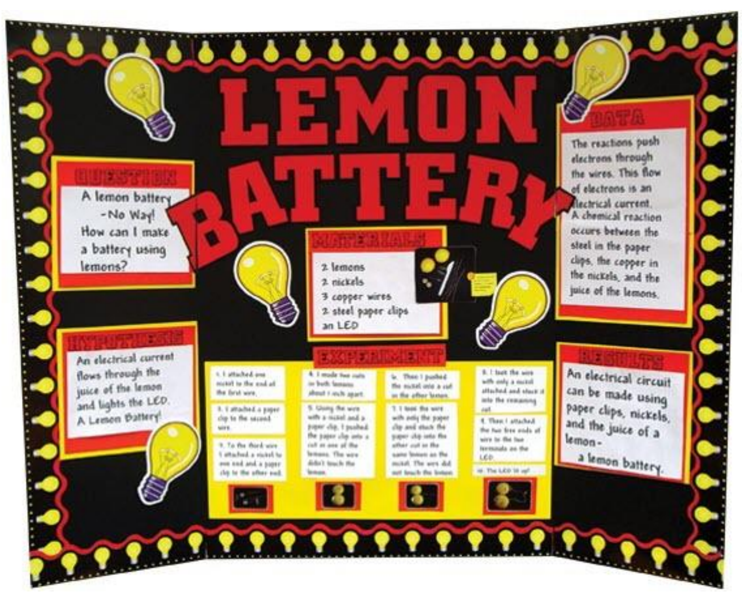
- Purchase colored construction paper or repositionable borders at your local office supply store or at Amazon.

- Repeat one of the main 3 to 5 contrasting colors from your color scheme. This will create a cohesive design.

- Because it makes a frame around the display board, it draws the viewer into the space just as a frame around a picture.

- The border also helps the viewer to concentrate on the board and invites them in to take a closer look.

  Notice how the homemade border matches the color scheme. It is quite an eye-catching board with only 5 colors, including the background black board.



- Attach three-dimensional objects to the display board at the fair - not at home.

- Look at more examples of display boards in the Appendix of this book.

Pictures

Use photos, diagrams or illustrations to present non-numerical data or to propose models that explain your results. Don't put text on top of any of these images.

- 8" X 10" and 5"x 7" are excellent sizes for your display board. Choose one size for all your photos.
- Place them in sequential order.
- Remember to frame them in one of the 3 to 5 colors of your color scheme.
- Photo stores can enlarge them for you. Some print shops can usually reproduce them. Make one copy first to check the quality.
- Look here to learn about writing and displaying a caption.
- Follow the KIS principle - Keep it Simple!

Illustrations

- To create poster size images, first draw in pencil and then retrace your drawings and sketches.
- Using an Opaque Projector at school, tape a large piece of paper on the wall and trace the outline of your drawing projection.
- It is important to make the drawings in proportion to the other materials that are on your display board.
- Look here to learn about writing and displaying a caption.

Display Placed on the Table Top

Ask your science teacher if you are permitted to cover the table with a cloth. If so, coordinate the color with the color scheme of your display board.

Abstract and Project Report

- Place each sheet of the Abstract and Project Report in individual 3-ring plastic sheet protectors. They can be purchased at your local office supply store or on Amazon.com

- Adhering to your color scheme, put the Abstract and Project Report in a 3-ring notebook. Place the Abstract at the front of the notebook. Some teachers like to have the Abstract in a separate notebook. Others want you to display your Abstract on your display board.

- Print a label and place it on the front cover of the notebook. The label must read the title of your project

- Place the notebook(s) on the table in front of your display board.

Models and Equipment

- Do not allow the models, equipment or parts of the display hang over the table.

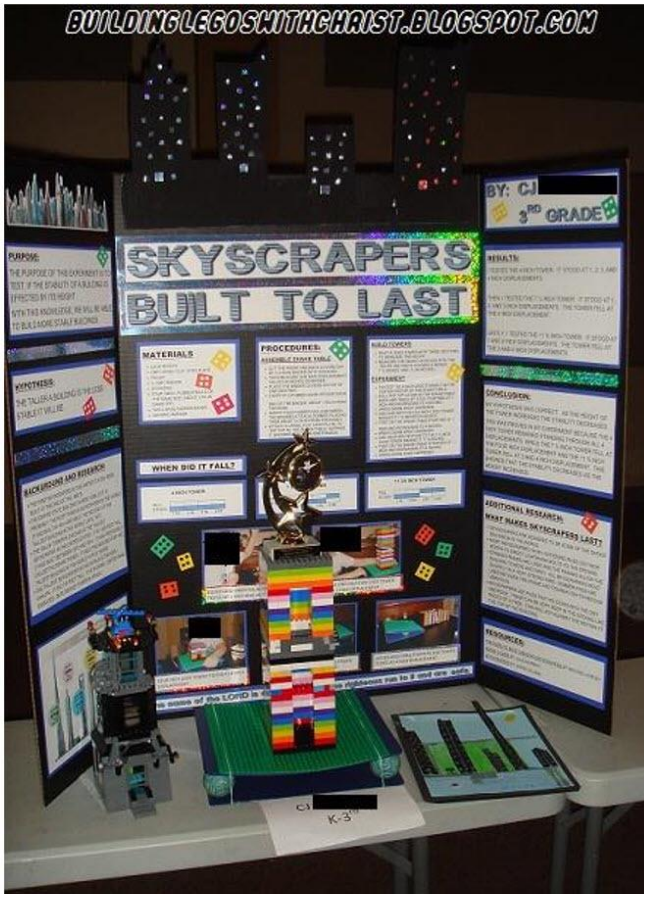
- Keep everything off the floor.

- Neatly arrange the model and or equipment in an organized fashion, along with your Abstract & Project Report and Design Notebook on the table in front of the display board.

- If your project is complicated, you may want to point out certain details. Here are a couple of ideas.

- If your equipment requires an electrical outlet, make sure that the wires are under the table so no one will trip and fall.

Example of items on the display table. (see next page)

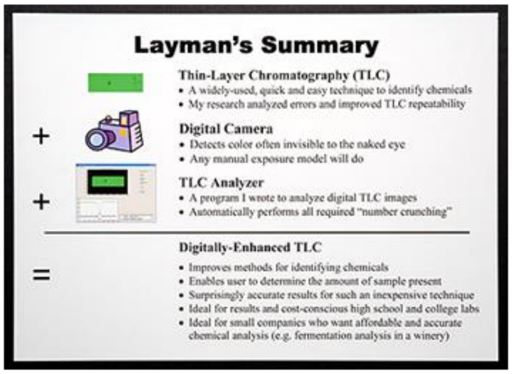


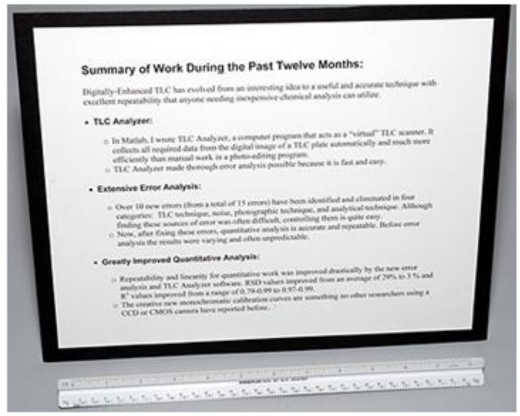
- Companion Board: Have a small black board that stands on the table that summarizes a process with explanation and images or explains terminology for a lay person.

[Elmer's 20" x 30" foam board] [Elmer's Project Stand] [X-Acto Knife]

With an X-ACTO knife, cut the board to 12" x 9". Here is a video that shows you how to cut the foam board so that it is not ragged. Practice on a scrap piece of foam board.

Print your information on white paper with black ink. Here are examples (Science Buddies: 2015)

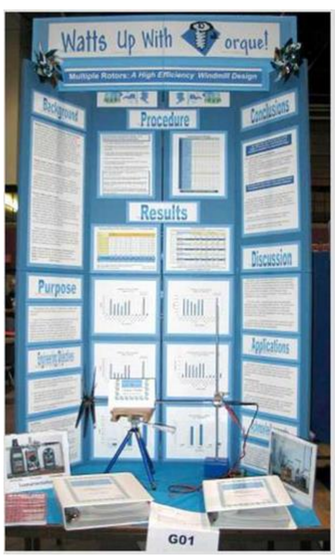




- If there is room on your large display board, you can have a summary section. Using bullet points and larger header style fonts, you can call attention to significant points. This is a separate section than the abstract.

What <u>Not</u> to Do with Your Display Board

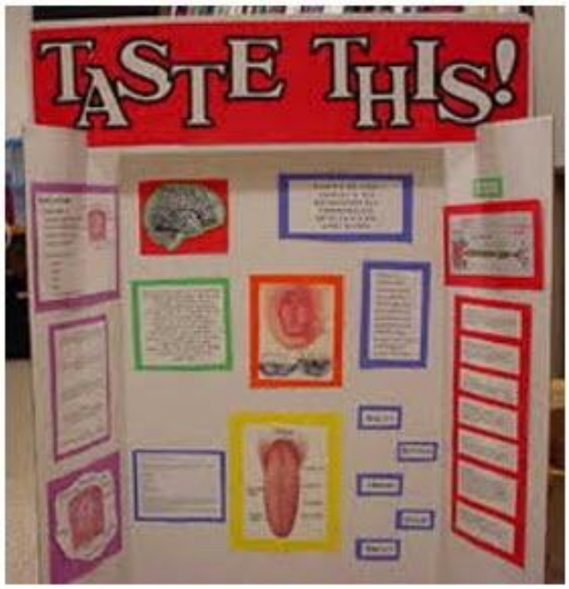
- Don't make the display board so tall that people cannot read what is at the top or stoop down to look at the bottom. Purchase or make a display board that is no taller than 48". Some Big Fairs (sometimes called a Top Fair) may suggest otherwise.



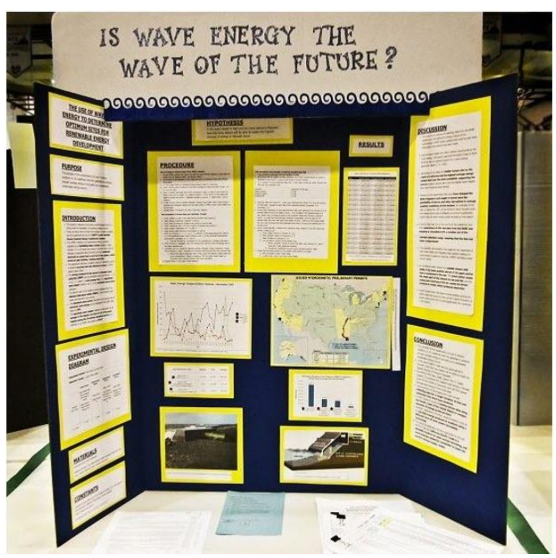
The board on the right looks good on the floor, but can you image how tall it is going to be when placed on a table at the fair?

- Don’t make a display board that has side panels that are so deep that the viewer would have to “walk” into the board to view the displays.

- Don’t make a header that casts a shadow on the top of the board. A shadow makes it difficult to read the text and captions.



Also, see how chaotic this board looks because of the different color boards around the papers and drawings.



Notice how this header casts a shadow on the left panel. It also interrupts the print on the top left side of that panel and the top of the middle panel.

Big Fairs / Top Fairs

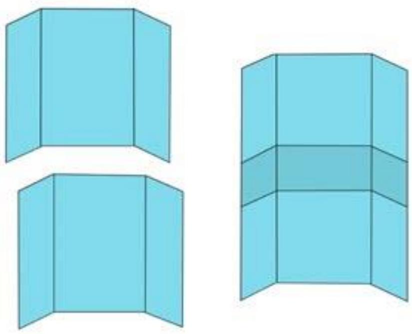
If you’ll be competing at a Big Fair (also called, Top Fairs) sponsored by Intel-ISEF, Siemen's, JSHS, Conrad Foundation Spirit of Innovation, major corporations or larger state and regional fairs, you will probably need to use a display board much larger than the standard 36 x 48” three panel boards that are seen at most science fairs.

Before you create your display, check the rules to see what the maximum display board size is, and be sure the board will fit in the vehicle that will take you to the science fair. If you’ll be shipping your display ahead, you’ll need to comply with the regulations of the shipping company so that your package arrives undamaged.

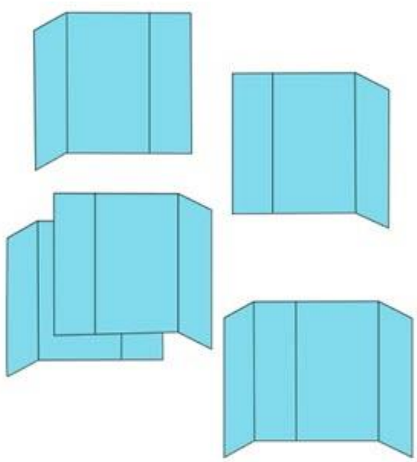
Constructing a Modular Display

Participants at big science fairs have another option. They can create their displays using two boards that can be easily transported or shipped and then assembled at the science fair. These are known as modular displays.

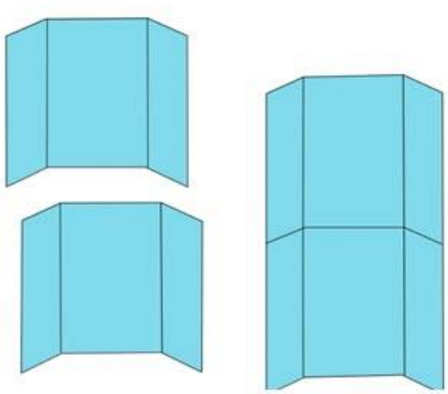
The modular display begins with a standard 36” x 48” tri-fold board as the foundation. You can then use another board to create more space for displaying your project:



A vertical overlap board slides up and Down over the standard board to enlarge the height of the display board.



A horizontal overlap board slides over a side panel to enlarge the center panel.



A stacked board sits on top of the standard board, effectively doubling your display space

You can combine these modular boards in any number of ways to create the exact look you want.

Construction Technique Tips

Trim the edges of the boards with an X-ACTO knife guided by a metal straight edge, such as a ruler or T-square. Because of the thickness of foam core boards, it is wise to make a shallower preliminary cut before the second final cut.

Protect the surface of your desk or table with a piece of heavy cardboard, scrap foam board or cutting mat.

The most secure way of assembling your modular display is to use small nuts and bolts at least ¾" long. Do this by making holes with an awl (a small pointed tool used for piercing holes) or nail.

Another way is to connect stacked boards is to use heavy packing tape or duct tape. Remember that when you remove the tape, you'll tear the board. To prevent that from happening, first lay down a strip of tape that will not be removed and attach the tape that will be removed to it.

More Suggestions for Display Boards Used at Top Fairs

- Do a rough sketch of how the components of your display will be put together. That way, when you print out the material for your board, you'll be aware of where the "breaks" between the panels are located.

- Before bringing your display to the science fair, go through a "dry run" assembly so you can work out any glitches ahead of time.

- Check the rules to see if you will need to display an official abstract or provide credits for the images.

- Make sure none of your images are prohibited.

- Remember, it's a good idea to number and provide captions for charts, tables and images.

- At a top fair, you will be expected to copy the style of professional journals. Refer to figures in your text, use their respective number.

When Traveling with Your Display Board Long Distances

If you have to travel long distances with your board, then you will want to protect it. Here are some suggestions.

- If traveling by car or plane, you can use a traveling case made by Road Case USA. Make sure to measure your board when it is folded so you know what size to get.

- Moving companies sell picture or mirror boxes.

- For a fee, moving companies may be willing to crate your display board.

- Images, photos and illustrations, if large, can be placed in a cardboard tube.

- Whatever method you use for transporting your board, be sure that you secure 2 types of shipping labels: 1) flat taped on label. 2) luggage label attacked to a strap or handle.

Display Board & Table Display Outcomes Checklist

Print this page, fill out the checklist, attach to your Design Notebook, and date your entry.

Place your display board on a table so you can view it as if it as it is going to be at the science fair. Then evaluate your display board as you go through each item on the checklist.

My Science Fair Project Display Board Includes All the Following Elements	✓
My display board and materials on the table include: ◦ Title ◦ Abstract (placed on board, on table in a folder or in front of the Project Report folder) ◦ Problem Statement ◦ Background Research ◦ Design Statement ◦ Requirements and Criteria ◦ Design Brief ◦ Proposed Solution ◦ Materials and Supply List ◦ Procedure ◦ Design ◦ Results (include data, charts and/or graphs) ◦ Conclusion ◦ Future Directions (placed on board and / or written in the Project Report) ◦ Project Report ◦ Design Notebook ◦ Acknowledgments (placed on board and / or written in the Project Report) ◦ Bibliography (placed on board and / or written in the Project Report)	
Display board is not more than 48" in height unless going to a Top Fair.	
Side panels not so wide that the viewer has to walk into the board to read the back panel.	
I only used 3 – 5 colors on my board including the black ink.	
The sections are organized like a newspaper and are easy to follow.	
The Project Title grabs the crowd's attention from across the room.	
The headings are visible to a person walking by my table.	
The fonts used for the text papers are easily read. They are at least 16 pt.	
All charts and tables convey accurate information about my project.	
All text, photos, illustrations, charts and graphs have a border around them. They are uniform in size and large enough to see when standing at my table.	
The display board is neat looking and draws the viewer into the board.	
I proofread the headings and materials on the display board.	
I read and followed all the rules for making the display board for my particular science fair.	

Are you all done? Did you finish your display board? Achieve your outcome? If YES – Congratulations! Remember… only proceed to the next step after you have completed your display board and table display items.

Day of the Science Fair

Time to Wow Your Teachers and Friends

How-To-Do A Classroom Science Fair Presentation

Rehearse Your Presentation
Letter "B" on the Timeline

I personally extend my congratulations to you for doing such an extraordinary job! You have truly lived the saying, "Being in action creates my success."

You have *reeeally* learned a lot. Believe it or not, it is all in your memory. Did you know that your brain is the most sophisticated computer and digital camera that exists on the planet? Therefore, it is not necessary for you to memorize your presentation. You lived it with every step that you took. So, don't concern yourself with knowing the facts.

Just like everything we have discussed so far, attitude is everything. Then comes know-how. The skills you are about to learn can be implemented if you do a presentation about your science fair project before your classmates or when you talk with the Judges at the fair.

Schedule Your Rehearsal Time
You will need to schedule 2 hours, 15-minute increments, for this section so you will feel totally relaxed when you do your presentation or have a discussion with the Judges.

Here is my special SECRET FILES #9 to help put you at ease.

Set the Stage for Your Presentation

It is natural to feel a little nervous when giving a presentation. How do you overcome that feeling? Well, the famous entertainer and singer, Bruce Springsteen, *The Boss*, calls the feelings in his stomach, throat and sweaty hands - ***EXCITED***.

Yes, change your words and you will change your experience! Did you know that Anthony Robbins, the motivational guru, jumps up and down, claps his hands and says a mantra before going on stage? What are you going to do?

Get *exciiited* about doing your presentation - of course! It's easy. Jump up and down! Shout hurray! When you are excited, the audience is excited and has fun.

Gestures

Be natural and relaxed. Have in your mind that the outcome of this experience is FUN!!! What you are really having is a conversation with a whole bunch of friends.

We naturally use gestures (movement with our hands) when we have a normal conversation without thinking about it. Using natural gestures won't distract from a presentation.

Be aware of the following:

- Keeping your hands out of your pockets
- Handcuffing your hands behind your back
- Keeping your arms crossed in front of your stomach or chest
- Keeping your hands on your hips
- Putting your hands anywhere on your face

Eye Contact

The rule of thumb for eye contact is 1 - 3 seconds per person. Try to focus on one person at a time. After all, these are your friends, your classmates! Don't just look at them, *see them.*

Using Your Voice

Pretend that you are talking to someone in the back of the room. Easy! This is called projecting your voice.

End of Secret Files 9

The Presentation

Take your time to rehearse, not memorize, your presentation in front of a mirror, your parents, grandparents, brothers and sisters, the dog. Videotaping yourself during these practices can be helpful.

Ask your "practice audience" to tell you what they especially liked and one thing that could improve your presentation. In this way your presentation will become a natural part of you - like having a conversation with your best friend about a topic that is very familiar to you.

Have you ever heard the saying?

> *Tell them what you're going to tell them...*
> *Tell them...*
> *Then tell them what you told them!*

So... how do you do that?

- **Tell them what you're going to tell them…**
  Develop a clear preview sentence of your main points. Give an introductory remark.

  - "I would like to tell you about how I started this project, what testing procedure I used, and the results."

  - "Before we begin, I'd like to tell you that I'm excited to tell you about my science project."

  - "Before we begin, I want to warn you, you're really going to have fun learning about my science fair project because it is so extraordinary."

  This is called a "preframe". It sets the audience's mood before you begin your presentation. Be sure to smile / laugh slightly ... to set the stage.

- **Tell them...**
  Talk through each point from your preview sentence.

- ◦ On small note cards put one key word to remind you of the main points you want to cover during your presentation.
- ◦ Number the cards...1, 2, 3, ... in case they get dropped!
- ◦ During your presentation keep the note cards in your hand or on a table / desk.

- o **Tell them what you told them...**
  Review the main points. "I've tried in these past few minutes to give you an overview of how this project started, what testing procedure was used, and the results.
  - ◦ Conclude your presentation with a strong, positive statement…
    "I learned.... (only one sentence). I would be happy to take any questions at this time.

How to Answer Questions After Your Presentation

- o Prepare for questions. Anticipate what questions your audience may have by thinking of questions that you may ask a presenter.
- o Repeat the question after someone asks his or her question.
- o Maintain your style. Answer your friend's question as if you were having a private conversation.
- o Involve the whole audience in your answer. Look at everyone when you answer the question.
- o Use your Display Board or Companion Board as a visual aid.
- o Ask your teacher a few days before the presentation if s/he has a pointer you can use. Remember to stand on the side of the board so you do not block your audience's view. (see next page)

SECRET FILES #10

Eliminating "Crutch" Words

Crutch words are words that are inserted into sentences as we talk. They give us time to think about what we want to say. After a while they become a habit and we are not aware that we are using them.

At the same time, they are very distracting and make us appear ineffective. Many times, people see you as not knowing what you are talking about. Here are some crutch words…

A bit	Felt/Touch	Seem/Seems/Seemed
Actually	Great	To
Almost	Heard/Hear	Seriously
Appear/Appeared to	Honestly	Shrugged his/Her/Their
As though	Like	Shoulders
Awesome	Literally	Slightly
Basically	Look	So
Beginning to	Nearly	Somehow
Can	Obviously	Super
Certainly	Probably	Totally
Decide	Quite	Very
Definitely	Rather	Virtually
Don't forget	Realize	Watch
Essentially	Really	Well
Fantastic	Right	Wonder
Feel/Felt like	See/Saw	

How to Overcome Using Crutch Words

1. Awareness is the beginning of change.
   Video tape your presentation while you practice talking to the Judge at the Science Fair. Notice what crutch word you use the most. Then give your presentation/conversation to the video camera again and do the following:

2. Stand tall. Carry yourself with confidence.

3. Concentrate on what you are saying. Don't worry about what you are going to say. Live in the moment, the now.

4. If you feel nervous, say the mantra that I taught you:

I live in my actions, not in my feelings.

5. Better yet, change your language: *I am excited. I am pumped!* **The language we use changes our experience.**

Accept that it is going to take time to change old habits. Studies show that it takes 21 days to change a behavior. Even if it takes longer than 21 days, stick with your plan. Eventually you will experience the change you worked so hard to achieve. By doing the above, you will gradually eliminate crutch words.

Tips on How to Prepare for the Day of the Science Fair

Prepare for your conversation with the Judges
Notice that I said, "conversation." This is not a presentation. You know what your project is all about because you created it and executed your plan from beginning to end.

Reread the section in this book on what questions the Judges may ask. Review your Project Report and Abstract. Those two documents will prepare you. Then write out a 1 to 2 sentence summary of what your project is all about. Include:

- how you got the idea for the project – purpose of your project
- how your project solves a problem or fulfills a need
- the results and conclusions you were able to draw

Judges want to know you understand the theory behind the project and why you got the results you did, so be prepared to answer their questions, even if they interrupt you in the middle of your explanation. You can point to items on your display board or companion board that illustrate points that you are making.

What Will the Judges Ask You?

- How much help you received from others
- What problems you ran into and how you fixed them
- The three most interesting things you learned when doing your project
- Why this research is important
- What further research you would consider doing
- Reread How Judges Think for more possible questions.

Practice explaining your project to a friend or family member. Are you using terms that are understandable to them? Can they understand your tables? If not, revise your explanation.

Create a list of questions and practice answering them. Videotaping yourself during these practices can be helpful. Eliminate those crutch words!

Remember, anytime you feel scared or unsure, just say to yourself, *I live in my actions, not in my emotions*.

Get up – stretch. It's been a great day! I know you have given your all today. Be proud of yourself. You have done an excellent job.

Today You Are Going to the Science Fair!
Letter "A" on Your Timeline

Today is the BIG DAY!
You are prepared.
You are confident.

Here is your 1st Prize ribbon in advance!
You deserve it for all your efforts

Is your science fair one where you'll have the chance to talk with the Judges? If so, consider yourself lucky! When you have the opportunity to explain your project in person, you can create a positive impression with the Judges and increase your chances of placing in the competition.

Some Last Minute Tips

- **Have fun!** That means to enjoy yourself and the experience of the Science Fair. It does not mean to party. What it does mean is to relax and enjoy the "fruits of your labor."

- **Remember, you are not your project or your display board**. The Judges are evaluating your project, not you. They will be looking at how you present it in written, oral and graphic form.

- **Practice one more time** what you are going to say to the Judges.

- **Be Professional and Dress Your Best**
  Make a first great impression with the Judges. It *reeealy* makes a difference. Have your image represent the pride and confidence you have in yourself and belief that you did an extraordinary, super, cool science fair project!

Dress neatly and professionally. Leave the jeans and shorts at home! When you give a professional appearance, the Judges will take you seriously and listen to what you have to say.

- **Bring extra materials** with you in case you have to fix up your display the last minute: scissors, tape, glue, letters, paper, table cloth.

  Have you included an extension cord if you need electricity for your project?

  Did you pack your Project Report with Bibliography and Abstract in a 3-ring notebook? How about your Design Notebook?

- **Bring something to keep you quietly busy** while the Judge visits other booths – a puzzle, book, sketchpad, notepad, homework. **DO NOT** engage in conversation on your cell phone! And no texting!!!!

- <u>After</u> you set up your display, **introduce yourself to the neighbors** on either side of your booth. Act friendly and professional. Ask them about their project. It will help pass the time until the Judge visits you.

- Have someone **take a picture of you** in front of your display with your camera or cell phone. Then put your cell phone on airplane mode.

- **Stay next to your display at all times.** You do not know when the Judges will come to talk with you. You will not get a high score if you are not present to explain what you did. Besides, you do not want curious hands to handle your display.

  If you have to go to the bathroom, tell a teacher so that she can alert the Judges. Come back as quickly as possible.

- **Keep your materials in order on the table** in front of the display.

- **The Judges**
  Remember, in the beginning of this book we discussed the importance of a person's attitude? Well, it is time to show your winning smile again. You know,

the one radiates from within your soul. Exude with positive enthusiasm. Show the Judges that you are interested in your project.

- Stand when the Judges talk with you.

- Be confident in your answers. Positive body language will show your confidence.

    - Hold your head up, straighten your shoulders.

    - Look the Judge directly into his/her eyes.

    - Do not drink, chew gum, eat or slouch.

    - Speak clearly. Do not mumble your words or talk fast. Do not use those distracting crutch words.

    - Give a firm handshake or elbow bump (not a crushing or smashing one) and introduce yourself, "Hi, Mr. (name is on their name tag), I am ____________. Good to meet you." Then keep quiet and let the Judge tell you what s/he wants to know.

    - Be honest. If you do not know the answer to a question, then tell the Judge the truth. Look the Judge in the eye, and with confidence, say, "I don't know the answer to that question, but I am curious to find out the answer."

    - Tell the Judges how your project is unique, creative or innovative. They love originality.

- Treat everyone you meet respectfully.

- **Ask the Judges for feedback <u>after</u> the fair is over**. (If they don't have time right then, ask permission to email them.)

  It is great to receive compliments, but constructive criticism is actually more valuable because it will help you make your project even better next time.

If you are going to submit your science fair project to one or more Top Fairs, the feedback and changes you make may help you to improve your chances of placing at the Fair(s).

Here are a couple of questions you can ask:

1. What can I do next time to improve my project?

2. Do you know someone who could possibly help me expand this project?

Last But Not Least…

This is your last SECRET FILES

When the day is over, after the judging takes place, find a private place where you can be by yourself. Close your eyes, take a deep breath through your nose and slowly blow the air out through your mouth. Then, ask yourself …

"What did I learn from this experience?"
Take another deep breath, pause, wait for an answer.
Then write whatever comes to your mind in your Design Notebook.
Close your eyes again, take a deep, circular breath and ask…

"What would I do differently next time?"
Take another deep breath, pause, wait for an answer.
Then write whatever comes to your mind in your Design Notebook.
Close your eyes again, take a deep, circular breath and ask…

"What would I do the same next time?"
Take another deep breath, pause, wait for an answer.
Then write whatever comes to your mind in your Design Notebook.
Close your eyes again, take a deep, circular breath and ask…

"What am I most proud about?"
Take another deep breath, pause, wait for an answer.
Then write whatever comes to your mind in your Design Notebook.
Close your eyes again, take a deep, circular breath and ask…

"How does that make me feel"?
Take another deep breath, pause, and wait for an answer.
Then write whatever comes to your mind in your Design Notebook.

Now… put a smile on your face… you know, the one that comes from within and makes you feel warm and fuzzy inside. When you have that special feeling of satisfaction, joy, happiness… whatever you want to call that feeling… literally pat yourself on the back, exuberantly, enthusiastically proclaim out loud,
"Congratulations, I did a greaaat job!"

APPENDIX

Parent's Guide to Science Fair Projects

Hi!
Before we get started, I want to share some thoughts and information that will be helpful to you.

What is the main topic of conversation at your dinner table?

> I have been thinking of inventing a robot! Is there unfamiliar talk about The Engineering Design Process, problem statement, finding a solution to a problem?

Science Fairs are annual events where students are encouraged to design and carry out scientific investigations. At some science fairs, students also compete for various levels of recognition.

I know when it's science fair time because eons of emails arrive every day from parents and students:

Will you send me a science fair project?

What is a good science fair project that my daughter can do for her 7th grade science fair?

Do you know of an easy science fair project?

Homework was my children's responsibility. I believe when children do *their own work*, they are the one that benefits.

I am hoping that this book will solve the challenges that students usual have when developing their own project. To come up with an idea and create a science fair project is the work of the STUDENT!

What for? Because going through the process of doing a science fair project is a metaphor for life! Thinking of an idea and bringing it into existence… isn't that what life's successes are all about? Learning to ride a bicycle, getting that first job, doing a homework assignment, cutting the grass… every action a person takes is a mini project that is first a thought and then followed by an action.

ACTION is what produces results. Every time a person goes from thought to action, they build a muscle of self-confidence in their own abilities.

When an adult takes over and does the work (all with loving intentions), we rob that child of future successes.

And, when students read *Student's Science Fair Guide to the Engineering Design Process* – page by page – they will be able to develop their own science fair projects. Your child <u>must</u> go through the process and complete all 8-steps of the Engineering Design Process. This is not an easy journey, but they can do it with you being their coach. Treat this book as a manual or guide.

In What Modality Does Your Child Learn?

This is probably the longest and most intense project your child will take on in the elementary grades or high school. With other school and family obligations the best student can get overwhelmed, hit a "roadblock" and cannot seem to stay on track or even finish their project. Fun and creativity come to a halt.

Sometimes getting stuck means your child needs to discover how s/he learns best. Find out what to do to help your child stay focused on a task, and much more! I took this test myself. It was right on target. Take an online learning profile which will give in-depth information to your child's style of learning.

What is Your Role in Working with Your Child?

1. You Are a Coach!

- **Enthusiastic patience** is the key without *saving* your child by stepping in and doing his / her project. Here are some helpful hints…

  Sergeant Shriver, former NBC anchorwoman Maria Shriver's father, was asked what he believed to be the most important attribute of being a parent. His response:

  > "*To be my children's cheerleader. They will get beaten up by others, told that they are not good enough or cannot achieve their dreams. I'm here to tell them that all things are possible with focus, hard work and faith*."

  Dr. Phil:

  > *"My job as a parent is to find out what my child is doing right and tell him. He will get beaten up when he is out in the world. I need to fortify him with positive self-esteem."*

- **What are the Attributes of a Coach/Cheerleader/Parent?**
  Love in your heart, spirit of fun, patience, a smile from within, belief in your child's greatness... BECAUSE YOUR CHILD IS GREAT! There isn't another creature on the planet that is like your child. Your child is unique!

  Tell your child...
  I believe in you.
  You are fun.
  You are great.
  I love you.
  I'm happy you're in my life!

- **What Does a Coach Do?** A coach asks great questions.
  What is a Great Question? Any question that starts with the word, "what."

  What else could you do to solve this?
  What is stopping you from going to the next step?

Why the Word "What"? It encourages the brain to go into its unconscious, tap into universal intelligence, and come up with a great answer.

What is a great answer? Whatever your child comes up with. After all, this is his or her project, journey, and learning experience.

Give a man a fish, you feed him for a day.
Teach a man to fish, you feed him for a lifetime!
Ancient Chinese Proverb

- What doesn't a coach do? S/he does not play the game. A coach is on the sidelines.

What resources will your child need in order to do an excellent science fair project?

After your child's project has been approved by his/her teacher, it is recommended that s/he meets with a parent and set a realistic budget. It is not necessary to spend a lot of money. What is a lot? That is different for each family.

So... what's important is to stay within a comfortable budget and ask yourself, "What resources will benefit my child and be an educational investment for his / her future?"

Keep in mind that projects for science fairs usually take about 2 to 3 months to complete.

Whether or not your children win recognition or go on to compete at a regional, state or national competition is not the focus. What is important is that they believe in their greatness by experiencing small successes along their journey.

Also, it is in the practice of science that they learn to approach life's challenges in a systematic way. This is what this event is really all about.

Time Management

Your child is going to make a schedule with a unique timeline. It will list all the expected dates of completion for each step of their project. Look at the Timeline and directions in the Appendix of this book.

Help your child complete the tasks assigned by allowing time at home, and to go to the library.

Safety Guidelines
https://www.societyforscience.org/isef/international-rules/display-safety-rules/

Science Fair Contest

Your child is invited to enter the Free, Online, International Science Fair Contest. Click on the link and get the details.

Legal Information
I am not an attorney, so I am not offering legal advice, just want to raise awareness. If your child does an original engineering or programming design that you believe can make money on the open market, or before your child becomes involved with a hospital, pharmaceutical company or business who may want to pay for their prototype or research, suggest you contact a legal professional.

There are non-profit groups that will give you legal advice. A family attorney or your local Chamber of Commerce can lead you in the right direction.

Parent's Chart on How to Help at Each Step

Project Step	How to Help	Do Not...
Step 1. Identifying a need	Discussing with your child whether a project idea is practical. Network and give names of experts to interview.	Pick an idea and project for your child. Your child needs to choose their own project so they stay excited. S/he must own this project. Do not write the Problem Statement.
Step 2. Doing background research	Be your child's chauffeur. Transport him / her to and from the library. You can help your child think of keywords by asking "what" questions. "What words do you think will lead you to information on this topic?"	Doing the keyword or Internet search. Printing the articles and links.
Step 3. Brainstorming and possible solutions	Compliment your child on the clever ideas s/he generated. Same with the drawings.	Do not give most of the ideas. Do not write the Design Brief.
Step 4. Design the solution **Step 5. Built the prototype** **Step 6. Test the prototype** **Step 7. Redesign, Retest and Rebuild the Prototype.**	Assisting in finding supplies and materials. Monitor safety. Only help to build something if your child asks for help.	Writing the experiment procedure. Designing, creating or making the solution. Only help with unsafe steps. Telling the child what to do.
Steps 6 and 7. Analyzing data and drawing conclusions.	Ask your child, "What would be the best way to record the data?" You can remind your child that the data needs to tie back to the patterns in the testing and used when drawing conclusions.	Create the spreadsheet. Make the graphs & tables. State the conclusion.
Step 8. Communicate results.	Allow your child to write his/her report alone! When practicing his presentation to the Judges, be an enthusiastic member of the audience. Display board: Transportation expert!	Hands off materials, supplies and the display board! Do not mention ideas for color scheme or placement of graphs, table, data or objects.
An Admirer		

Student Printables

Complete Engineering Design Process Checklist Check off the items as you complete them. This will keep you on track.	✓
Print the Table of Contents.	
Read the section, Before You Begin.	
Printed all the printables.	
Realistically dated my Timeline.	
Purchased items recommended on Shopping List 1.	
Set up my Design Notebook and using it.	
Using a Day-Timer	
Read the Overview section about the Design Process.	
Step 1 – Identify the Need ◦ Made a "bug" list. ◦ Generated Project Ideas ▪ Did an informal survey. ▪ Made a Mind Map. ◦ Wrote my Problem Statement. ◦ Printed and checked off all the items on the Problem Statement Outcomes Checklist. Attached the Checklist to my Design Notebook and dated the entry.	
Met with my teacher and parent(s). Both approved my project.	
Step 2. Read the section on Background Research. ◦ Formulated questions about who my target users would be. ◦ Completed the Project Research worksheet. ◦ Completed Keyword worksheet. ◦ Completed the Question Word worksheet. ◦ Researched target user / customer's needs. ◦ Developed questions to ask about similar products that already exist that solve the target user's needs. ◦ Researched how to make the product and how it could possibly work. ◦ Asked possible target users questions about their needs. ◦ Asked competitors questions who have a similar product. ◦ Asked questions of specialists and people from various backgrounds to assist me in finding similar products. ◦ Asked experts and target users what science concepts would be best to learn about. ◦ Did a patent search and found 3 patents similar to what I want to do. ◦ Found at least 3 original research references. ◦ Wrote notes on note cards. ◦ Kept track of bibliography on Bibliography Worksheet. ◦ Printed and checked off all the items on the Engineering Background Research Plan Outcomes Checklist. Attached the Checklist to my Design Notebook and dated the entry.	

Step 3. Read the section about Brainstorming Ideas & Possible Solutions. ° Did one or all of the following: ▪ Brainstorming ▪ Doodling and sketching. ▪ Wrote analogies. ▪ Examined existing products. ▪ Slept on it. ° Wrote the Design Requirements detailing the criteria. Identified the needs and constraints. ° Wrote a Design Brief. ° Completely filled in the Engineering Design Process Proposal Form Worksheet. ° Printed and completed all the items on the Engineering Possible Solutions Outcomes Checklist. Attached the Checklist to my Design Notebook and dated the entry.	
Met with teacher and parent(s). Received approval from both to design a preliminary solution to the problem.	
Step 4. Design Your Solution(s) ° Decided how I am going to measure the change my invention/solution makes. ° Made a chart showing the attributes of my product and each solution. ° Designed preliminary drawings for my solution using one or more of the following methods of development: ▪ Drawings / sketches ▪ Prototype ▪ Storyboards ° Chose the Best Solution. (Used a Design Matrix) ° Made a detailed Materials & Supply List and purchased needed items. ° Wrote a step-by-step procedure to build my prototype. ° Printed and completed all the items on the Engineering Preliminary Design Outcomes Checklist. Attached the Checklist to my Design Notebook and dated the entry.	
Met with Teacher and Parent(s). Got approval from both to build a working prototype.	
(If entering a Top Fair) Filled out the entry form and submitted it.	
Step 5. Built a working prototype.	
Step 6. Tested my prototype. ° Developed a test plan. ° Had at least 3 to 5 target users test the prototype. ° Collected data. ° Made charts and graphs. ° Analyzed data. ° Drew conclusions. ° Worked out glitches with target users. ° Collected data as did testing, also used target users' input. ° Analyzed data and looked for patterns. ° Printed and completed all items on the Engineering Data Analysis Checklist, Graph	

Checklist and Drawing Conclusions Checklist. Attached the Checklist to my Design Notebook and dated the entry.	
Step 7. Refined, Redesigned, Retested as needed using feedback from target users.	
Step 8. Communicate the Engineering Results ◦ Wrote my Project Report – Includes ▪ Title Page ▪ Table of Contents ▪ Introduction ▪ Problem Statement ▪ Background Research ▪ Design Statement and Criteria – Design Brief ▪ Preliminary drawings, final prototype design, step-by-step procedure ▪ Materials & Supply list ▪ Tested prototype - charts and graphs that show data collected during testing ▪ Refining, redesigning and retesting of product. ▪ Data Analysis Discussion ▪ Conclusions drawn. ▪ Future direction ▪ Bibliography ▪ Acknowledgments • Wrote 1st draft and had someone edit it. • Wrote 2nd draft and rechecked it. • Wrote final copy and printed on clean white paper either from my home printer or at a print shop. ◦ Wrote my abstract. Includes: ◦ Project Title (included my name, school name) ◦ Purpose of the Project - Problem Statement ◦ Description of the procedure I used ◦ Results ◦ Conclusions	
Constructed an exhibit or display board	
Prepared for and gave a verbal presentation to my class (optional)	
Prepared my 3 to 5-minute presentation for the Judge(s)	
Day of the Science Fair ◦ Dressed neatly and professionally ◦ Prepared a box with extra materials to fix the display board if necessary. Also included all equipment and extension cord (if needed). ◦ Brought something to keep myself quietly busy at the fair. ◦ Did the "Last But Not Least" exercise.	

Timeline - Print and Insert dates according to directions on next page.

	TIMELINE	
AF	Before You Begin	
AE	Timeline	
AD	Shopping List 1	
AC	Science Log	
AB	Day-Timer	
AA	The Scientific Method Topic Research	
Z	Choose a Category	
Y	Determine Subcategory	
X	Choose a Topic	
W	Teacher & Parent's Approval	
V	Big Question	
U	Proposal Form	
T	Teacher & Parent's Approval	
S	Background Research Bibliography Note Cards	
R	Keywords & Keyword Questions	
Q	Determine Variables	
P	Write Hypothesis	
O	Meet with Your Teacher	
N	Write Experimental Procedure	
M	Materials List	
L	Teacher & Parent's Approval	
K	Shopping List 2	
J	Do Your Experiment	
I	Analyze Data & Draw Conclusions Analyze Data	
H	Draw Conclusions	
G	Communicating Your Results Write Project Report Paper Write 1st Draft	
F	Write 2nd Draft	
E	Write Final Copy	
D	Write Abstract	
C	Design & Create a Display Board	
B	Rehearse Presentation	
A	Day of Science Fair	

Start Here

Directions on How to Use the Timeline

Start at point **A** and move left along the horizontal line to point **AJ**.
Write the dates the OUTCOMES are to be completed in the light gray boxes.

Examples:
Input the date of the Science Fair Exhibit in top gray box of A.
Move to the left to line B, input the date you will do your Presentation.

Continue inserting the dates until you finish writing the date you are going to start your science fair project.

Design Notebook Printable

The most difficult thing about keeping a science notebook is remembering to use it at each and every point in your project. With such a detailed account of your project activities, you will be able to go back to a previous step whenever you need to. You will also find it easier to analyze your data and write your Project Report.

Fold this checklist into ¼, using a paper clip, put it in your Day-Timer. At the end of each day, move it to the following day.

What goes into your notebook? Everything…Everyday!

The more details you can include, the better:

- Any form of brainstorming that led you to making a decision.
- Every step you took - one by one.
- What worked and what didn't work.
- What you had to go back and re-do.
- What new insights you achieved.
- What conclusions you drew.

Remember to:

- Write or print legibly
- Put a date next to each entry
- Number each page in sequential order
- Keep the entries in sequential order
- Do not leave an empty page
- Place an X in large empty spaces on each page
- Make entries brief – do not need to use complete sentences
- Write the Problem Statement and Design Step by Step
- Write down any thoughts that come to you about the project
- Make notes of all test measurements
- Make a note of anything you need to look up later
- Staple or tape all loose papers on the day you wrote or printed them.

Things to include:

- Drawings or photographs of your lab setup or results of experiments (you can glue or staple these into your notebook)
- Any math calculations (so you can double check later, if you need to)
- Phone numbers or email addresses of anyone you have contacted about your project

Bibliography Worksheet

No.	Source: ☐ Book	☐ Magazine	☐ Newspaper	☐ Website	☐ Research Journal	☐ Other
Author's Last Name		First Name			Middle Initial	
Date Published		Publication/Website Title				
Title of Article						
Place Published (if applicable)		Publisher (books only)			Editor (if applicable)	
Edition		Volume Number		Page Number(s)		
Website is a ☐ Company	☐ Organization	☐ Government	☐ Newspaper/Magazine		☐ Research Journal	☐ Other
Website URL: http://						

No.	Source: ☐ Book	☐ Magazine	☐ Newspaper	☐ Website	☐ Research Journal	☐ Other
Author's Last Name		First Name			Middle Initial	
Date Published		Publication/Website Title				
Title of Article						
Place Published (if applicable)		Publisher (books only)			Editor (if applicable)	
Edition		Volume Number		Page Number(s)		
Website is a ☐ Company	☐ Organization	☐ Government	☐ Newspaper/Magazine		☐ Research Journal	☐ Other
Website URL: http://						

No.	Source: ☐ Book	☐ Magazine	☐ Newspaper	☐ Website	☐ Research Journal	☐ Other
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Date Published		Publication/Website Title				
Title of Article						
Place Published (if applicable)		Publisher (books only)			Editor (if applicable)	
Edition		Volume Number		Page Number(s)		
Website is a ☐ Company	☐ Organization	☐ Government	☐ Newspaper/Magazine		☐ Research Journal	☐ Other
Website URL: http://						

No.	Source: ☐ Book	☐ Magazine	☐ Newspaper	☐ Website	☐ Research Journal	☐ Other
Author's Last Name		First Name			Middle Initial	
Date Published		Publication/Website Title				
Title of Article						
Place Published (if applicable)		Publisher (books only)			Editor (if applicable)	
Edition		Volume Number		Page Number(s)		
Website is a ☐ Company	☐ Organization	☐ Government	☐ Newspaper/Magazine		☐ Research Journal	☐ Other
Website URL: http://						

Background Project Research

Keyword Worksheet

Name____Date_________________

1. Engineering Design Process: Define the problem you plan to solve (Who) need(s) (what) because (why)____

   ____

2. List the keywords / phrases in the above sentence plus find more keywords. These keyword phrases will help you to research your topic. Here are free online resources for you to search for your keywords and keyword phrases: Magazines, Encyclopedia, http://www.encyclopedia.com, http://www.wikipedia.org

   List 12 – 20 keyword phrases below:

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

   ______________________________________ ______________________________________

3. Using your notes, write one keyword phrase in the top right corner of a note card. Do project research by reading magazines, encyclopedias, journals, etc. and trace the information back to its original source.

Question Word Worksheet

Date______________

Question Word	Possible Questions to Ask Print a set of Worksheets for each keyword or keyword phrase that you research. You may not be able to fill out all the questions for each keyword. You may have some of your own questions you would like to ask.
Who Target User and/or buyer	Who needs my solution? Who wants my solution? Who would purchase my solution? Who invented a similar solution? Name the solution.
What	What would the target user need or want with this type of solution? What would the target user be willing to pay for this type of solution? What size would my target user want this solution to be? What would be the size of the various parts? What are the important characteristics of my solution? ◦ Criteria? ◦ Constraints?

	What would be the best algorithm, material(s) or component(s) for building each of the parts of my solution? What solutions on the market fill a similar need? ◦ What are their strengths? ◦ What are their weaknesses? ◦ What are the most important features that these solutions have?
Where	Where will my solution be used?
Why	Why did the engineers of other solutions design them the way they did?
How	How would a solution like this work?

	How will I measure the performance of my solution? ◦ How can I measure my design's improvement over existing designs?

As you do your research think of the type of formulas or equations you might need to analyze the results of your experiments. Record these in your Design Notebook.

Staple or tape all the Question Word Worksheets in your Design Notebook after you completed them.

Patent Research Worksheet

Name____Date_________________

Suggested websites to use:

U.S. Patent & Trademark Office: http://www.uspto.gov/

Search for Patents here: http://www.uspto.gov/patents-application-process/search-patents

Conduct Research to Answer the Following Questions:

1. What is the design solution that you are working on?
2. What are some possible products that relate to the design challenge?
3. Give at least three examples of existing patents that relate to you design solution. Patent name: Website: Brief description: How this relates to your design: Patent name: Website: Brief description: How this relates to your design:

Patent name:

Website:

Brief description:

How this relates to your design:

Design Brief Worksheet

Name____Date________________

Your Design Brief Worksheet will gather all the information you researched and simplify it into one condensed summary. After you completed the worksheet tape it in the Design Notebook.

Definition of the problem you want to solve: Who needs _________________ (what) ___________________because__________________
From your background research, describe how the products that are on the market do not solve the problem.
In detail, describe the target user.
List only what is needed to solve the design requirements of your product. Keep in mind that you must have the materials, money and tools to create your working design in the time allotted. If you are in doubt, then decide whether or not you can make some trade-offs.

Proposal Form for Individuals & Teams

Print 3 copies - 1 each for your parent, teacher and Design Notebook. Bring copies to your meeting.

Name____Date________________

My problem statement: (Who) needs (what) because (why)

Go Over This Checklist with Your Teacher and a Parent	✓
The topic I chose will hold my interest for the next 2 weeks to 3 months.	
I have researched the problem and have found 3 resources on the topic. List the resources. 1. 2. 3.	
My Design Solution will fix the problem because….	
My Design ° The change I will measure. ° What I will do ° Materials	
My materials and equipment are easy to obtain at a low price	
I have enough time to design and build by prototype before the assignment is due.	
I am going to enter a science fair. My intended project meets their rules and requirements. I checked with science fair officials to see if my project needs approval.	

My parent(s) and I have discussed the above science fair project and I am committed to completing the project on time.

Student's Signature Date

I have discussed the above science fair project with my child and believe s/he is committed to following through to completion and on time. I agree to supervise the safety of the project that my child performs at home.

Parent's Signature Date

I approve the Problem Statement and respective science fair project.

Teacher's Signature Date

Design Matrix

Directions
Engineering Analysis

If you are the only one doing your project, then you need to get a team together to help you with the following process. Ask family members, classroom friends, other friends, or a combination. People who are 10 yrs. old thru adult are good ages. Five to 10 people make a good team.

Step 1: List Criteria

a. Your team needs to make a list of all the criteria you can think of to compare your design solutions. In other words, what are the important design considerations?

- Weight
- Size
- Appearance
- Time to produce
- Cost to produce
- Ease of use
- Availability of materials
- Environmental impact
- Safety

b. Make a list of eight criteria in your Design Notebook.

Step 2: Assign Priority Values to Criteria

a. Complete the **interaction matrix** here by listing the criteria both in rows down on the left, and columns across the top. Don't worry about filling out the ROW TOTAL, COLUMN TOTAL, or NORMALIZED VALUE yet.

b. You or a volunteer facilitator poll your all your friends (if you are working alone) or your team for the opinions of the relative importance of one criterion over another.

   For example, the first blank cell on the top left tallies the number of people who feel that Criterion 1 is more important than Criterion 2. Let's say you have five people in your team, and three people feel that Criterion 1 is more important than Criterion 2. Then you would write the number "3" in the first blank cell on the top left. You would then write a "2" in the off-diagonal cell – the one that ranks Criterion 2 against Criterion 1.

c. Add the number across the rows for each criterion and write this number in the ROW TOTAL cell.

d. Add the ROW TOTAL numbers down the column to find the COLUMN TOTAL.

Step 3: Normalize the Priority Values

a. To get a better feel for the relative priority values, you can "normalize" the values, which means to calculate each value as a proportion of a total that equals 1.

b. To normalize the priority values, divide each ROW TOTAL by the COLUMN TOTAL and write this number in the corresponding NORMALIZED VALUE cell.

Step 4: Compare Alternative Designs

Go to this page

a. Order the normalized criteria values from largest to smallest. This puts the most important criteria at the top of the list.

b. Write each criterion and its corresponding normalized criteria value in the **decision matrix**.

c. Rank each alternative design concept according to how well the group feels that concept could satisfy each of the design criteria identified. Use a consistent scale (for example 0 – 5). A ranking of 0 means that the team feels the design concept does not meet the criterion at all. A 5 means that the team feels the design concept meets the criterion perfectly.

d. Multiply each ranked value in the gray cells below each design alternative.

e. Multiply each ranked value by the normalized criterion value and write this number to the right of the ranked value for each design alternative.

f. Sum these multiplied values and write them in the corresponding TOTAL cell.

Step 5: Analyze Results

a. The design alternative with the highest value (as shown in the TOTALS row) is the alternative that best meets the selected criteria. Design alternatives with significantly lower values can be discarded. The design alternative with the highest score may be selected or you can select the alternative that received the highest score for the majority of the categories.

b. Which is the design alternative with the highest value?

c. Which idea will you proceed to design?

Template for Design Matrix

Interaction Matrix

Criteria	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	ROW TOTAL	NORMALIZED VALUE
Criterion 1										
Criterion 2										
Criterion 3										
Criterion 4										
Criterion 5										
Criterion 6										
Criterion 7										
Criterion 8										
COLUMN TOTAL										

Comparing Alternative Designs

Decision Matrix

Criteria (ranked by normalized criteria value)	Normalized Priority Value	Design Alternative #1	______	Design Alternative #2	______	Design Alternative #3	______	Design Alternative #4	______	Design Alternative #5	______
TOTALS											

Information Pages

50 Engineering Science Fair Project Idea Questions

- Design a structure that is constructed using different materials that are stronger, last longer, more corrosion resistance or have more elasticity... be creative. The trick is to make certain your measurements are truly comparable to each other.
- Can I make a wind generator that is more efficient, quieter than what exists now?
- Can the drying time or level of hair dryness be improved when using a hand-held hair dryer?
- How can a backpack be made more ergonomic friendly for a primary school age child?
- Can the sound of a forced hot air hand dryer be reduced and still be effective? First find out what people consider acceptable for hand drying time.
- Design and make a local weather computer model that is better than what already exists.
- Do birds discriminate between patterned and unpatterned anemometers?
- Design a better way to get supplies to people in need after a disaster. 1st you will have to see what is being done now.
- Design a modern lighthouse to promote the lighthouse preservation.
- How can airplane seats be made more comfortable?
- How can amusement rides be made safer?
- Design a whole town made from recycled material.
- What are some possible uses for the space on a flat rooftop?
- How can hydropower be used to lift an object?
- How can the quality of a microphone be improved?
- Which model window solution will keep a room the warmest?
- How can we design standards for every job function in a warehouse to ensure optimal productivity?
- Design a longer lasting light bulb.
- Design a stronger light bulb that does not break.
- Design a refrigerator that does not break down in 7 years.
- Design a mechanism that allows cars to drive automatically on a road.
- How does the shape of a car effect the amount of wind resistance that arises when the car is in motion?
- How much weight can a helium balloon lift?
- How tall can you build a tower using only a sheet of paper?
- How will the size and shape of a balloon rocket affect how fast and how far the balloon will travel on a string?
- Is solar energy really practical?
- Is there a backpack that is more economically designed so that your back will not get injured?
- Is there a better way to have arm rests made in the movie so that I don’t have to share?
- Is there a more sanitary way to keep toilets in public restrooms clean?

- How can energy that is expended to do one thing, power a machine to do something different?
- What can be done so that when one light goes out on a Christmas tree, all the lights do not go out?
- What is the most fuel-efficient combination?
- What can be done to cut down the echo noise in your school cafeteria?
- What can you do with a swim cap to optimize its ability to decrease drag in water? Can you alter the shape? Does one material work substantially better than another?
- What is the best material to put in a sandbag to block water, such as during a flood?
- Design an airplane wing shape or size that has more aerodynamics lift when tested under different wind tunnel fan speeds?
- What processes and systems can you implement in a building to increase productivity and reduce cost?
- What technology solutions can we customize to drive further improvements in a customer's business?
- What type of pulley setup makes lifting a heavy load easiest?
- What type of model window will keep a room the warmest?
- Design a boat that will not sink.
- Which material has the strongest tensile strength?
- Which shapes are the most structurally strong?
- Which windmill design is the sturdiest?
- Which wind turbine will be better at producing work?
- Design a purification system that sits on top of the counter that filters more contaminants that exists now.
- Design a reverse osmosis purification system that sits on top of the counter.
- Improve upon a free-standing water purification system – one that will remove more metals and contaminants – where you can use tap water that goes into a container. The filter would be replaced every ___ months and sit inside the container.
- Identify a problem in your community or home that you would like to design a solution to address it.
- Identify a problem that needs a solution when you are engaged in a hobby.

Science Fair Topics to Avoid

First and Foremost – any project in violation of SCVSEFA, ISEF or California Education Rules and Regulations will most likely not be accepted. If you are intending to move on to TOP level fairs, then do not take a chance. Do not do one of the following projects.

1. Engineering projects without a functional purpose i.e., building a Lego tower, building a bridge that is not unique and subject to some sort of testing
2. Projects that do not have a measurable endpoint. (Results should be expressed in units of size, mass, speed, time, volume, replication rate, etc.
3. Any project involving the distillation of alcohol. (not permitted because illegal)
4. Any topic that requires dangerous, hard to find, expensive or illegal materials.
5. Any topic that requires drugging, pain, or injury to a live vertebrate animal, including humans.
6. Any topic that creates unacceptable risk (physical or psychological) to a human subject.
7. Any topic that involves collection of tissue samples from living humans or vertebrate animals.
8. Requires taste, memory, emotion, strength, etc. of individuals because subjective
9. Pyramid power
10. Comparison of items or programs. (You can improve upon a product.)

OK With Variables. If you are in middle school and intend to go on to Top Fairs or expand on your project in years to come, I would avoid the following topics.

11. Basic solar collectors or ovens (OK if engineering design variables included)
12. Basic flight testing, e.g., planes, rockets

The following project may meet all requirements but often do not win awards because it is too commonly encountered by judges. With frequently done projects, acceptance may be granted if they have an original twist with exceptional thoroughness and solid scientific method.

13. Comparison of strength in different bridge designs.

Reasons to Avoid a Topic

- If the experiments don’t involve numerical measurement such as a survey.

- Data tends to be unreliable when people give a subjective response.

- When many students in the past have done a project on this subject.

- When the rules of the science fair are violated.

Example of Judges Score Sheet

Project #: ______________ Project Title: ____________________________________

Write the project number and the title of the project in the spaces above. Score each of the projects assigned to you in the category that you are judging. Different judges will be assigned different categories, so it is only necessary for you to score **your assigned category. Circle the number that best equates to the quality of the project.**

PROJECT OBJECTIVES

	Not Present					Excellent
Originality of investigation	0	1	2	3	4	5
Clearly stated/answerable question	0	1	2	3	4	5
Hypothesis phrased as a testable idea with a rationale	0	1	2	3	4	5

Score _____/15

PROJECT IMPLEMENTATION

	Not Present				Excellent
Experiment addresses question and is clearly explained	0	1	2	3	4
Independent research and experimentation	0	1	2	3	4
Experimental procedures explained thoroughly so the methods are repeatable by others	0	1	2	3	4
Clearly defined variables and controls	0	1	2	3	4
Measurable results	0	1	2	3	4

Score _____/20

DATA COLLECTION AND PRESENTATION

	Not Present				Excellent
Evidence of multiple trials	0	1	2	3	4
Complete data set and summary data are presented	0	1	2	3	4
Data presentation includes tabular, graphic, and written forms	0	1	2	3	4

Data presentation includes discussion of variability of results

Not Present				Excellent
0	1	2	3	4

Score _____/16

DATA INTERPRETATION

Use of appropriate data types and graphics

Not Present					Excellent
0	1	2	3	4	5

Data are used to draw a well-supported conclusion

Not Present					Excellent
0	1	2	3	4	5

Background information is used to help interpret data

Not Present					Excellent
0	1	2	3	4	5

Conclusion includes reflection of possible effects of methods on results

Not Present					Excellent
0	1	2	3	4	5

Score _____/20

PROJECT PRESENTATION

Creativity of presentation

Not Present				Excellent
0	1	2	3	4

Clear and thorough explanation of investigation

Not Present				Excellent
0	1	2	3	4

Neat and organized presentation of information

Not Present				Excellent
0	1	2	3	4

Score _____/12

RELATED STUDY REPORT

Clearly written in student's own words

Not Present			Excellent
0	1	2	3

Clearly relates to science fair project

Not Present			Excellent
0	1	2	3

References are properly cited

Not Present			Excellent
0	1	2	3

Score _____/9

INTERVIEW

Student is present	**Not Present**				**Excellent**
	0				4
Student conveys understanding of concepts related to project					
	Not Present				**Excellent**
	0	1	2	3	4

Score _____/8

TOTAL SCORE ____________/100

Questions asked at the San Diego Science & Engineering Science Fair

- How did you decide to do this particular project?
- Is this project an expansion of one you did before? If so, what did you add or change?
- How does this science fair project apply to real life?
- How did you determine your sample size?
- Did you choose any statistical test? If so, how did you determine which one to use?
- Will you explain your graph / chart / photos me to?
- Please explain your procedure.
- What do your results mean? How can they apply to everyday life?
- How many times did you test your device or program?
- How is this project different from others that you researched?
- What was the most interesting background reading that you did?
- Where did you get your science supplies?
- What new skills, if any, did you learn by doing this science fair project?
- What is the most important thing you learned by doing this project?
- What changes would you make if you continued this project?

ISEF Judging Criteria

1. Research Problem (10 pts)

   ___description of a practical need or problem to be solved

   ___definition of criteria for proposed solution

   ___explanation of constraints

2. Design and Methodology (15 pts)

   ___exploration of alternatives to answer need or problem

   ___identification of a solution

   ___development of a prototype/model

3. Execution: Construction and Testing (20pts)

   ___prototype demonstrates intended design

   ___prototype has been tested in multiple conditions/trials

   ___Prototype demonstrates engineering skill and completeness

4. Creativity (20 pts)

   ___project demonstrates significant creativity in one or more of the above criteria

5. Presentation (35 pts)

   a. <u>Poster</u> (10 pts)

      ___logical organization of material

      ___clarity of graphics and legends

      ___supporting documentation displayed

   b. <u>Interview</u> (25 pts)

      ___clear, concise, thoughtful responses to questions

      ___understanding of basic science relevant to project ___understanding interpretation and limitations of results and conclusions

___degree of independence in conducting project

___recognition of potential impact in science, society and/or economics

___quality of ideas for further research

___for team projects, contributions to and understanding of project by all members

The Judges Engineering Design “Interview”

If you are entering your project in a fair where you will be judged on your work, it is important to know what the Judges expect before you begin your project.

When you answer the Judge’s questions, be excited. This is your opportunity to explain your project. Don’t talk too fast. Help the Judge(s) to understand your project by speaking clearly in an organized manner so it’s not confusing. The Judges want to know how much you know about your project.

Here is what they may ask:

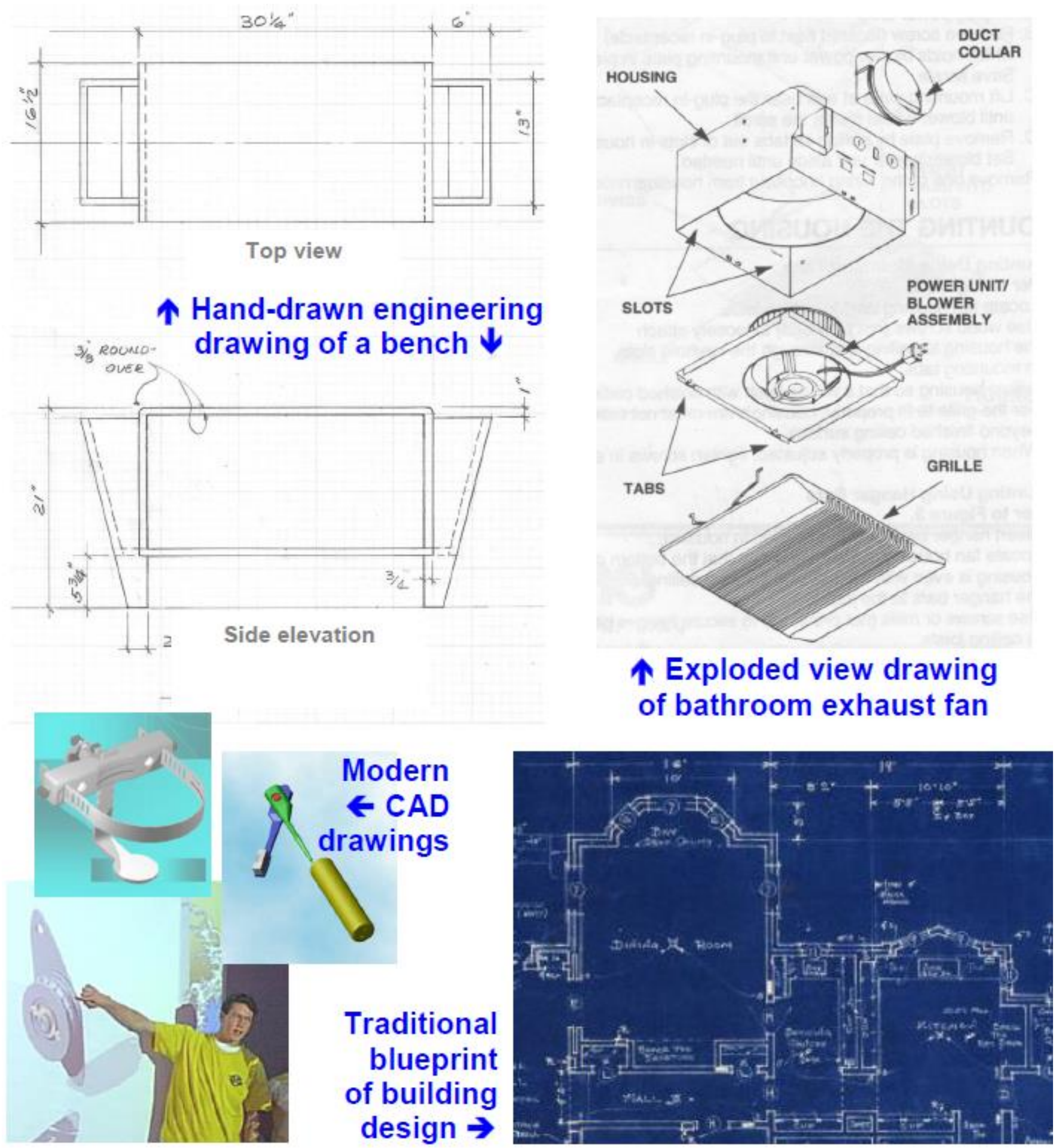
- How you prepared it
- How you set it up
- What information you discovered
- What the information means
- What your conclusion is

Possible Questions Judges May Ask

- Will you please explain where you got your idea for the project?
- What did you do to personalize it and make it unique?
- Explain the project method you used.
- Why did you choose the subject?
- Explain your results.
- How does the result relate to your background knowledge?
- How does the result help you in understanding the world better?
- How does you project have practical applications?
- Will you give me some specific background knowledge about your subject?
- What problems did you run into?
- How could you have improved your project?
- If you did it again, what would you do differently?
- What questions do you have now?
- What are some of the ideas you learned from your research?
- How did the research help you with your project?
- How much time did you spend on your project?
- How did others help you or give you ideas?
- How did you test the prototype?

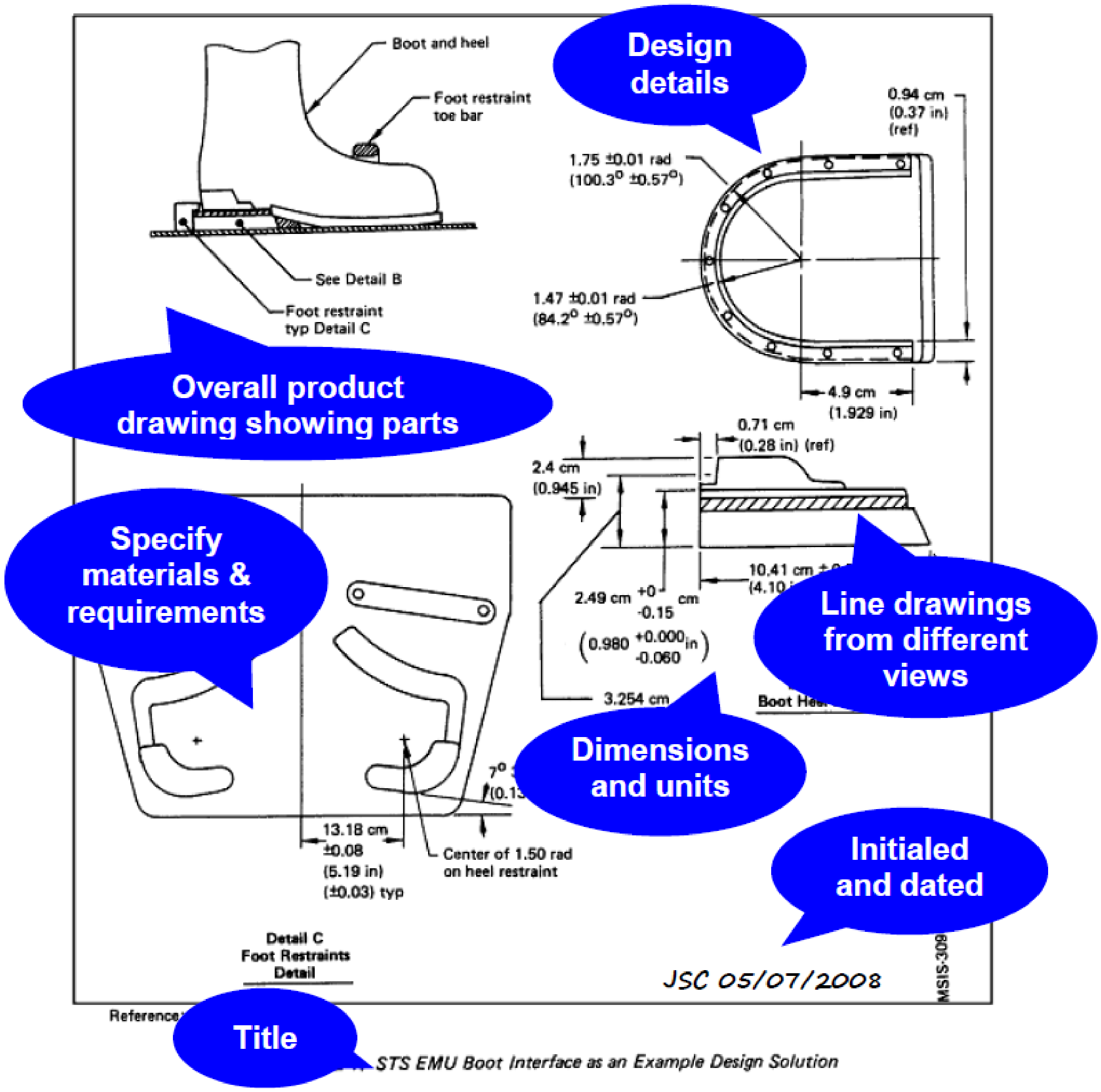
Types of Engineering Drawings

Manufacturing a Final Product



Engineering Drawing Components

Include all these components in your engineering drawings.



Reference ... STS EMU Boot Interface as an Example Design Solution

Intel ISEF Categories & Subcategories

The categories of science listed below are those used by Intel ISEF.

Your local, regional, state and country fairs **may or may not** choose to use these categories. Check with the Fair you are participating in for the category listings that are at your level of competition.

Animal Sciences (Code: ANIM)

This category includes all aspects of animals and animal life, animal life cycles, and animal interactions with one another or with their environment.

Examples of investigations included in this category would involve the study of the structure, physiology, development, and classification of animals, animal ecology, animal husbandry, entomology, ichthyology, ornithology, and herpetology, as well as the study of animals at the cellular and molecular level which would include cytology, histology, and cellular physiology.

Subcategories of Animal Sciences:

Animal Behavior (BEH): The study of animal activities which includes investigating animal interactions within and between species or an animal's response to environmental factors. Examples are animal communication, learning, and intelligence, rhythmic functions, sensory preferences, pheromones, and environmental effects on behaviors, both naturally and experimentally induced.

Cellular Studies (CEL): The study of animal cells involving the use of microscopy to study cell structure and studies investigating activity within cells such as enzyme pathways, cellular biochemistry, and synthesis pathways for DNA, RNA, and protein.

Development (DEV): The study of an organism from the time of fertilization through birth or hatching and into later life. This includes cellular and molecular aspects of fertilization, development, regeneration, and environmental effects on development.

Ecology (ECO): The study of interactions and behavioral relationships among animals, and animals and plants, with their environment and with one another.

Genetics (GEN): The study of species and population genetics at the organismal or cellular level.
Nutrition and Growth (NTR): The study of natural, artificial, or maternal nutrients on animal growth, development, and reproduction including the use and effects of biological and chemical control agents to control reproduction and population numbers.

Physiology (PHY): The study of one of the 11 animal systems. This includes structural and functional studies, system mechanics, and the effect of environmental factors or natural variations on the structure or function of a system. Similar studies conducted specifically at the cellular level should select the cellular studies subcategory.

Systematics and Evolution (SYS): The study of animal classification and phylogenetic methods including the evolutionary relationships between species and populations. This includes morphological, biochemical, genetic, and modeled systems to describe the relationship of animals to one another.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Behavioral and Social Sciences (Code: BEHA)

The science or study of the thought processes and behavior of humans and other animals in their interactions with the environment studied through observational and experimental methods.

Subcategories:

Clinical and Developmental Psychology (CLN): The study and treatment of emotional or behavioral disorders. Developmental psychology is concerned with the study of progressive behavioral changes in an individual from birth until death.

Cognitive Psychology (COG): The study of cognition, the mental processes that underlie behavior, including thinking, deciding, reasoning, and to some extent motivation and emotion. Neuro-psychology studies the relationship between the nervous system, especially the brain, and cerebral or mental functions such as language, memory, and perception.

Physiological Psychology (PHY): The study of the biological and physiological basis of behavior.

Sociology and Social Psychology (SOC): The study of human social behavior, especially the study of the origins, organization, institutions, and development of human society. Sociology is concerned with all group activities-economic, social, political, and religious.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Biochemistry (Code: BCHM)

The study of the chemical basis of processes occurring in living organisms, including the processes by which these substances enter into, or are formed in, the organisms and react with each other and the environment.

Subcategories:

Analytical Biochemistry (ANB): The study of the separation, identification, and quantification of chemical components relevant to living organisms.

General Biochemistry (GNR): The study of chemical processes, including interactions and reactions, relevant to living organisms.

Medicinal Biochemistry (MED): The study of biochemical processes within the human body, with special reference to health and disease.

Structural Biochemistry (STR): The study of the structure and or function of biological molecules.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Biomedical and Health Sciences (Code: BMED)

This category focuses on studies specifically designed to address issues of human health and disease.

It includes studies on the diagnosis, treatment, prevention or epidemiology of disease and other damage to the human body or mental systems. Includes studies of normal functioning and may investigate internal as well as external factors such as feedback mechanisms, stress or environmental impact on human health and disease.

Subcategories of Biomedical and Health Sciences:

Disease Diagnosis (DIS): The systematic examination, identification, and determination of disorders and disease through examination at the whole body or cellular levels.

Disease Treatment (TRE): The use of pharmaceuticals and other therapies, including natural and holistic remedies, intended to improve symptoms and treat or cure disorders or disease.

Drug Development and Testing (DRU): The study and testing of new chemical therapies intended to improve symptoms and treat or cure disorders and disease. This testing could include any platform from tissue culture to preclinical animal models. This will include establishing a drug's safety profile and ensuring regulatory compliance.

Epidemiology (EPI): The study of disease frequency and distribution, and risk factors and socioeconomic determinants of health within populations. Epidemiologic investigations may include gathering information to confirm existence of disease outbreaks, developing case definitions and analyzing epidemic data, establishing disease surveillance, and implementing methods of disease prevention and control.

Nutrition (NTR): The study of food, nutrients and dietary need in humans, and the effects of food and nourishment on the body. These studies may include the effects of natural or supplemental nutrients and nutrition.

Physiology and Pathology (PHY): The science of the mechanical, physical, and biochemical functions of normal human tissues, organs, and body systems; and the study of disease-related tissue and organ dysfunction. Pathophysiology is the study of the conditions leading up to a diseased state and includes an investigation of the disturbance responsible for causing the disease.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Cellular and Molecular Biology (Code: CELL)

This is an interdisciplinary field that studies the structure, function, intracellular pathways, and formation of cells. Studies involve understanding life and cellular processes specifically at the molecular level.

Subcategories:

Cell Physiology (PHY): The study of the cell cycle, cell function, and interactions between cells or between cells and their environment.

Genetics (GEN): The study of molecular genetics focusing on the structure and function of genes at a molecular level.

Immunology (IMM): The study of the structure and function of the immune system at the cellular level. This includes investigations of innate and acquired (adaptive) immunity, the cellular communication pathways involved in immunity, cellular recognition, graft vs host and host vs graft disease, and interactions between antigens and antibodies.

Molecular Biology (MOL): The study of biology at the molecular level. Chiefly concerns itself with understanding the interactions between the various systems of a cell, including the interrelationships of DNA, RNA and protein synthesis and learning how these interactions are regulated, such as during transcription and translation, the significance of introns and exons or coding issues.

Neurobiology (NEU): The study of the structure and function of the nervous system at the cellular or molecular level.

OTH Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Chemistry (Code: CHEM)

Studies exploring the science of the composition, structure, properties, and reactions of matter not involving biochemical systems.

Subcategories:

Analytical Chemistry (ANC): The study of the separation, identification, and quantification of the chemical components of materials.

Computational Chemistry (COM): A study that applies the discipline and techniques of computer science and mathematics to solve large and complex problems in Chemistry.

Environmental Chemistry (ENV): The study of chemical species in the natural environment, including the effects of human activities, such as the design of products and processes that reduce or eliminate the use or generation of hazardous substances.

Inorganic Chemistry (INO): The study of the properties and reactions of inorganic and organometallic compounds.

Materials Chemistry (MAT): The chemical study of the design, synthesis and properties of substances, including condensed phases (solids, liquids, polymers) and interfaces, with a useful or potentially useful function, such as catalysis or solar energy.

ORG Organic Chemistry (ORG): The study of carbon-containing compounds, including hydrocarbons and their derivatives.

Physical Chemistry (PHC): The study of the fundamental physical basis of chemical systems and processes, including chemical kinetics, chemical thermodynamics, electrochemistry, photochemistry, spectroscopy, statistical mechanics and astro-chemistry.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Computational Biology and Bioinformatics (Code: CBIO)

Studies that primarily focus on the discipline and techniques of computer science and mathematics as they relate to biological systems

Studies that include the development and application of data-analytical and theoretical methods, mathematical modeling and computational simulation techniques to the study of biological, behavior, and social systems.

Subcategories of Computational Biology and Bioinformatics:
Biomedical Engineering (BME): The application of engineering principles and design concepts to medicine and biology for healthcare purposes.

Computational Biomodelling (MOD): Studies that involve computer simulations of biological systems most commonly with a goal of understanding how cells or organism develop, work collectively and survive.

Computational Evolutionary Biology (EVO): A study that applies the discipline and techniques of computer science and mathematics to explore the processes of change in populations of organisms, especially taxonomy, paleontology, ethology, population genetics and ecology.

Computational Neuroscience (NEU): A study that applies the discipline and techniques of computer science and mathematics to understand brain function in terms of the information processing properties of the structures that make up the nervous system.

Computational Pharmacology (PHA): A study that applies the discipline and techniques of computer science and mathematics to predict and analyze the responses to drugs.

Genomics (GEN): The study of the function and structure of genomes using recombinant DNA, sequencing, and bioinformatics.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Earth and Environmental Sciences (Code: EAEV)
Studies of the environment and its effect on organisms/systems, including investigations of biological processes such as growth and life span, as well as studies of Earth systems and their evolution.

Subcategories:
Atmospheric Science (AIR): Studies of the earth's atmosphere, including air quality and pollution and the processes and effects of the atmosphere on other Earth systems as well as meteorological investigations.

Climate Science (CLI): Studies of Earth's climate, particularly evidential study of climate change.
Environmental Effects on Ecosystems (ECS): Studies of the impact of environmental changes (natural or as a result of human interaction) on ecosystems, including empirical pollution studies.

Geosciences (GES): Studies of Earth's land processes, including mineralogy, plate tectonics, volcanism, and sedimentology.

Water Science (WAT): Studies of Earth's water systems, including water resources, movement, distribution, and water quality.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Embedded Systems (Code: EBED)
Studies involving electrical systems in which information is conveyed via signals and waveforms for purposes of enhancing communications, control and/or sensing.

Subcategories:
Circuits (CIR): The study, analysis, and design of electronic circuits and their components, including testing.

Internet of Things (IOT): The study of the interconnection of unique computing devices with the existing infrastructure of the Internet and the cloud.

Microcontrollers (MIC): The study and engineering of microcontrollers and their use to control other devices.

Networking and Data Communication (NET): The study of systems that transmit any combination of voice, video, and/or data among users.

Optics (OPT): The use of visible or infrared light instead of signals sent over wires. The study and development of optical devices and systems devoted to practical applications such as computation.

Sensors (SEN): The study and design of devices that transmit an electrical response to an external device.

Signal Processing (SIG): The extraction of signals from noise and their conversion into a representation for modeling and analysis.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Energy: Chemical (Code: EGCH)

Studies involving biological and chemical processes of renewable energy sources, clean transport, and alternative fuels.

Subcategories:

Alternative Fuels (ALT): Any method of powering an engine that does not involve petroleum (oil). Some alternative fuels are electricity, methane, hydrogen, natural gas, and wood.

Computational Energy Science (COM): A study that applies the discipline and techniques of computer science and mathematics to solve large and complex problems in Energy Science.

Fossil Fuel Energy (FOS): Studies involving energy from a hydrocarbon deposit, such as petroleum, coal, or natural gas, derived from living matter of a previous geologic time and used for fuel.

Fuel Cells and Battery Development (FUE): The study, analysis and development of fuel cells and batteries that convert and/or store chemical energy into electricity.

Microbial Fuel Cells (MIC): The study of fuel cells that use or mimic bacterial interactions found in nature to produce electricity.

Solar Materials (SOL): The study of materials used to convert and store solar energy through chemical changes. This includes topics such as thermal storage and photovoltaic materials.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Energy: Physical (Code: EGPH)
Studies of renewable energy structures/processes including energy production and efficiency.

Subcategories:
Hydro Power (HYD): The application of engineering principles and design concepts to capture energy from falling and running water to be converted to another form of energy.

Nuclear Power (NUC): The application of engineering principles and design concepts to capture nuclear energy to be converted to another form of energy.

Solar (SOL): The application of engineering principles and design concepts to capture energy from the sun to be converted to another form of energy.

Sustainable Design (SUS): The application of engineering principles and design concepts to plan and/or construct buildings and infrastructure that minimize environmental impact.

Thermal Power (THR): The application of engineering principles and design concepts to capture energy from the Earth's crust to be converted to another form of energy.

Wind (WIN): The application of engineering principles and design concepts to capture energy from the wind to be converted to another form of energy.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Engineering: Mechanics (Code: ENMC)
Studies that focus on the science and engineering that involve movement or structure. The movement can be by the apparatus or the movement can affect the apparatus.

Subcategories:
Aerospace and Aeronautical Engineering (AER): Studies involving the design of aircraft and space vehicles and the direction of the technical phases of their manufacture and operation.

Civil Engineering (CIV): Studies that involve the planning, designing, construction, and maintenance of structures and public works, such as bridges or dams, roads, water supply, sewer, flood control and, traffic.

Computational Mechanics (COM): A study that applies the discipline and techniques of computer science and mathematics to solve large and complex problems in Engineering Mechanics.

Control Theory (CON): The study of dynamical systems, including controllers, systems, and sensors that are influenced by inputs.

Ground Vehicle Systems (VEH): The design of ground vehicles and the direction of the technical phases of their manufacture and operation.

Industrial Engineering-Processing (IND): Studies of efficient production of industrial goods as affected by elements such as plant and procedural design, the management of materials and energy, and the integration of workers within the overall system. The industrial engineer designs methods, not machinery.

Mechanical Engineering (MEC): Studies that involve the generation and application of heat and mechanical power and the design, production, and use of machines and tools.

Naval Systems (NAV): Studies of the design of ships and the direction of the technical phases of their manufacture and operation.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Environmental Engineering (Code: ENEV)

Studies that engineer or development processes and infrastructure to solve environmental problems in the supply of water, the disposal of waste, or the control of pollution.

Subcategories:

Bioremediation (BIR): The use of biological agents, such as bacteria or plants, to remove or neutralize contaminants. This includes phytoremediation, constructed wetlands for wastewater treatment, biodegradation, etc.

Land Reclamation (ENG): The application of engineering principles and design techniques to restore land to a more productive use or its previous undisturbed state.

Pollution Control (PLL): The application of engineering principles and design techniques to remove pollution from air, soil, and/or water.

Recycling and Waste Management (REC): The extraction and reuse of useful substances from discarded items, garbage, or waste. The process of managing, and disposing of, wastes and hazardous substances through methodologies such as landfills, sewage treatment, composting, waste reduction, etc.

Water Resources Management (WAT): The application of engineering principles and design techniques to improve the distribution and management of water resources.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Materials Science (Code: MATS)

The study of the characteristics and uses of various materials with improvements to their design which may add to their advanced engineering performance.

Subcategories:

Biomaterials (BIM): Studies involving any matter, surface, or construct that interacts with biological systems. Such materials are often used and/or adapted for a medical application, and thus comprise whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function.

Ceramic and Glasses (CER): Studies involving materials composed of ceramic and glass – often defined as all solid materials except metals and their alloys that are made by the high-temperature processing of inorganic raw materials.

Composite Materials (CMP): Studies involving materials composed of two or more different materials combined together to create a superior and unique material.

COM Computation and Theory (COM): Studies that involve the theory and modeling of materials.

Electronic, Optical and Magnetic Materials (ELE): The study and development of materials used to form highly complex systems, such as integrated electronic circuits, optoelectronic devices, and magnetic and optical mass storage media. The various materials, with precisely controlled properties, perform numerous functions, including the acquisition, processing, transmission, storage, and display of information.

Nanomaterials (NAN): The study and development of nanoscale materials; materials with structural features (particle size or grain size, for example) of at least one dimension in the range 1-100 nm.

Polymers (POL): The study and development of polymers; materials that have a molecular structure consisting chiefly or entirely of a large number of similar units bonded together, e.g., many synthetic organic materials used as plastics and resins.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Mathematics (Code: MATH)

The study of the measurement, properties, and relationships of quantities and sets, using numbers and symbols. The deductive study of numbers, geometry, and various abstract constructs, or structures.

Subcategories:
Algebra (ALB): The study of algebraic operations and/or relations and the structures which arise from them. An example is given by (systems of) equations which involve polynomial functions of one or more variables.

Analysis (ANL): The study of infinitesimal processes in mathematics, typically involving the concept of a limit. This begins with differential and integral calculus, for functions of one or several variables, and includes differential equations.

Combinatorics, Graph Theory and Game Theory (CGG): The study of combinatorial structures in mathematics, such as finite sets, graphs, and games, often with a view toward classification and/or enumeration.

Geometry and Topology (GEO): The study of the shape, size, and other properties of figures and spaces. Includes such subjects as Euclidean geometry, non-Euclidean geometries (spherical, hyperbolic, Riemannian, Lorentzian), and knot theory (classification of knots in 3-space).

Number Theory (NUM): The study of the arithmetic properties of integers and related topics such as cryptography.

Probability and Statistics (PRO): Mathematical study of random phenomena and the study of statistical tools used to analyze and interpret data.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Microbiology (Code: MCRO)
The study of micro-organisms, including bacteria, viruses, fungi, prokaryotes, and simple eukaryotes as well as antimicrobial and antibiotic substances

Subcategories:
Antimicrobials and Antibiotics (ANT): The study of a substance that kills or inhibits the growth of a microorganisms.

Applied Microbiology (APL): The study of microorganisms having potential applications in human, animal or plant health or the use of microorganisms in the production of energy.

Bacteriology (BAC): The study of bacteria and bacterial diseases and the microorganisms responsible for causing a disease.

Environmental Microbiology (ENV): The study of the structure, function, diversity and relationship of microorganisms with respect to their environment. This includes the study of biofilms.

Microbial Genetics (GEN): The study of how microbial genes are organized and regulated and their involvement in cellular function.

Virology (VIR): The study of viruses and viral diseases.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Physics and Astronomy (Code: PHYS)
Physics is the science of matter and energy and of interactions between the two. Astronomy is the study of anything in the universe beyond the Earth.

Subcategories:
Atomic, Molecular, and Optical Physics (AMO): The study of atoms, simple molecules, electrons and light, and their interactions.

Astronomy and Cosmology (AST): The study of space, the universe as a whole, including its origins and evolution, the physical properties of objects in space and computational astronomy.

Biological Physics (BIP): The study of the physics of biological processes.

Computational Physics (COM): A study that applies the discipline and techniques of computer science and mathematics to solve large and complex problems in Physics and Astrophysics.

Condensed Matter and Materials (MAT): The study of the properties of solids and liquids. Topics such as superconductivity, semi-conductors, complex fluids, and thin films are studied.

Instrumentation (INS): Instrumentation is the process of developing means of precise measurement of various variables such as flow and pressure while maintaining control of the variables at desired levels of safety and economy.

Magnetics, Electromagnetics and Plasmas (MAG): The study of electrical and magnetic fields and of matter in the plasma phase and their effects on materials in the solid, liquid or gaseous states.

Mechanics (MEC): Classical physics and mechanics, including the macroscopic study of forces, vibrations and flows; on solid, liquid and gaseous materials.

Nuclear and Particle Physics (NUC): The study of the physical properties of the atomic nucleus and of fundamental particles and the forces of their interaction.

Optics, Lasers, Masers (OPT): The study of the physical properties of light, lasers and masers.

Quantum Computation (QUA): The study of the laws of quantum mechanics to process information. This includes studies involving the physics of information processing, quantum logic, quantum algorithms, quantum error correction, and quantum communication.

Theoretical Physics (THE): The study of nature, phenomena and the laws of physics employing mathematical models and abstractions rather than experimental processes.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Plant Sciences (Code: PLNT)
Studies of plants and how they live, including structure, physiology, development, and classification.

Subcategories:
Agronomy (AGR): Application of the various soil and plant sciences to soil management and agricultural and horticultural crop production. Includes biological and chemical controls of pests, hydroponics, fertilizers and supplements.

Growth and Development (DEV): The study of a plant from earliest stages through germination and into later life. This includes cellular and molecular aspects of development and environmental effects, natural or manmade, on development and growth.

Ecology (ECO): The study of interactions and relationships among plants, and plants and animals, with their environment.

Genetics/Breeding (GEN): The study of organismic and population genetics of plants. The application of plant genetics and biotechnology to crop improvement. This includes genetically modified crops.

Pathology (PAT): The study of plant disease states, and their causes, processes, and consequences. This includes effects of parasites or disease-causing microbes.

Physiology (PHY): The study of functions in plants and plant cells. This includes cellular mechanisms such as photosynthesis and transpiration, and how plant processes are affected by environmental factors or natural variations.

Systematics and Evolution (SYS): The study of classification of organisms and their evolutionary relationships. This includes morphological, biochemical, genetic, and modeled systems.
Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Robotics and Intelligent Machines (Code: ROBO)

Studies in which the use of machine intelligence is paramount to reducing the reliance on human intervention

Subcategories:

Biomechanics (BIE): Studies and apparatus which mimic the role of mechanics in biological systems.

Cognitive Systems (COG): Studies/apparatus that operate similarly to the ways humans think and process information. Systems that provide for increased interaction of people and machines to more naturally extend and magnify human expertise, activity, and cognition.

Control Theory (CON): Studies that explore the behavior of dynamical systems with inputs, and how their behavior is modified by feedback. This includes new theoretical results and the applications of new and established control methods, system modeling, identification and simulation, the analysis and design of control systems (including computer-aided design), and practical implementation.

Robot Kinematics (KIN): The study of movement in robotic systems.

Machine Learning (MAC): Construction and/or study of algorithms that can learn from data.

Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Systems Software (Code: SOFT)

The study or development of software, information processes or methodologies to demonstrate, analyze, or control a process/solution

Subcategories:

Algorithms (ALG): The study or creation of algorithms - step-by-step procedure of calculations to complete a specific task in data processing, automated reasoning and computing.

Cybersecurity (CYB): Studies involving the protection of a computer or computer system against unauthorized access or attacks. This can include studies involving hardware, network, software, host or multimedia security.

Databases (DAT): Studies that create or analyze data organization for ease of access, management and update.

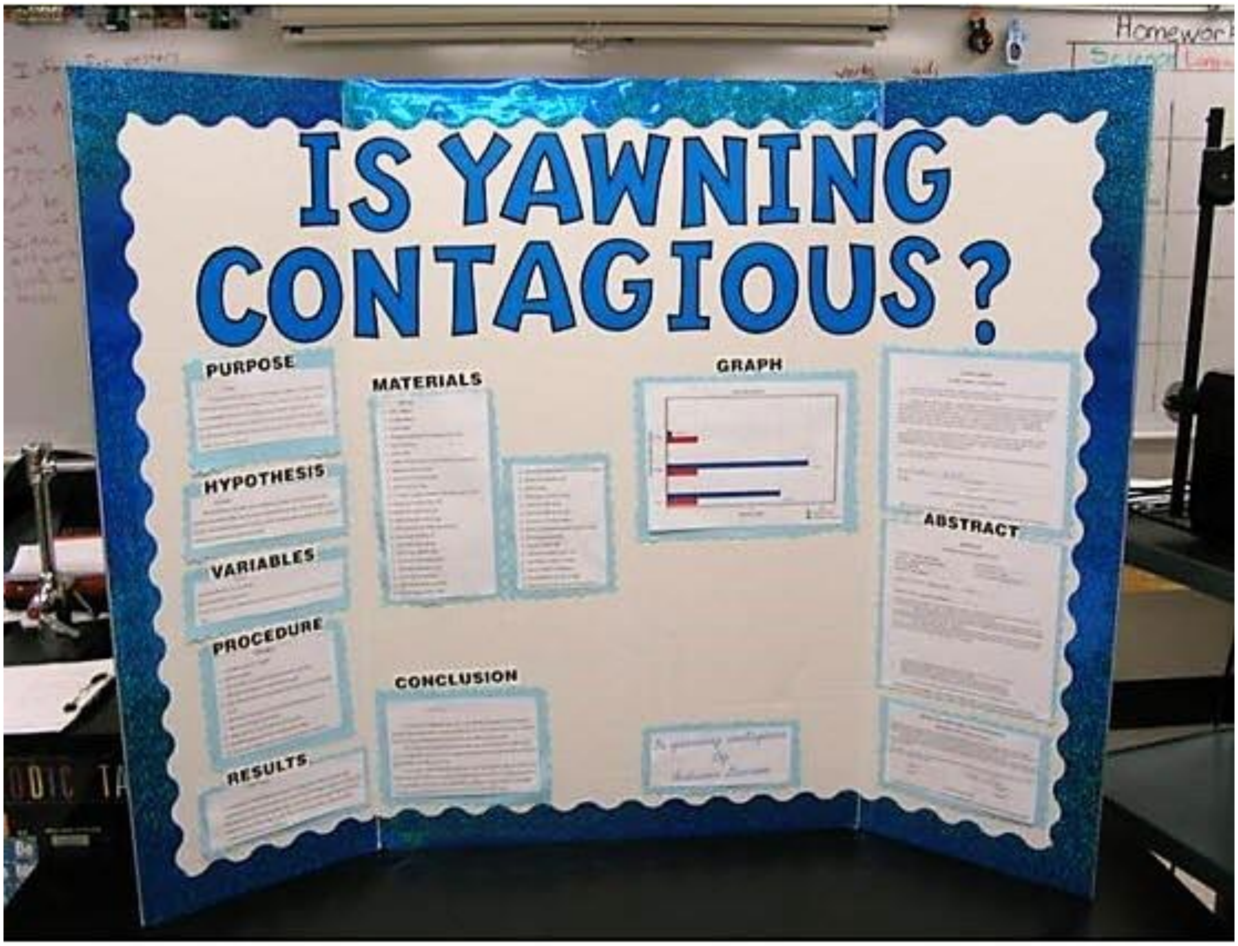
Operating Systems (SYS): The study of system software responsible for the direct control and management of hardware and basic system operations of a computer or mobile device.

Programming Languages (PRG): Studies that involve the development or analysis of the artificial languages used to write instructions that can be translated into machine language and then executed by a computer.

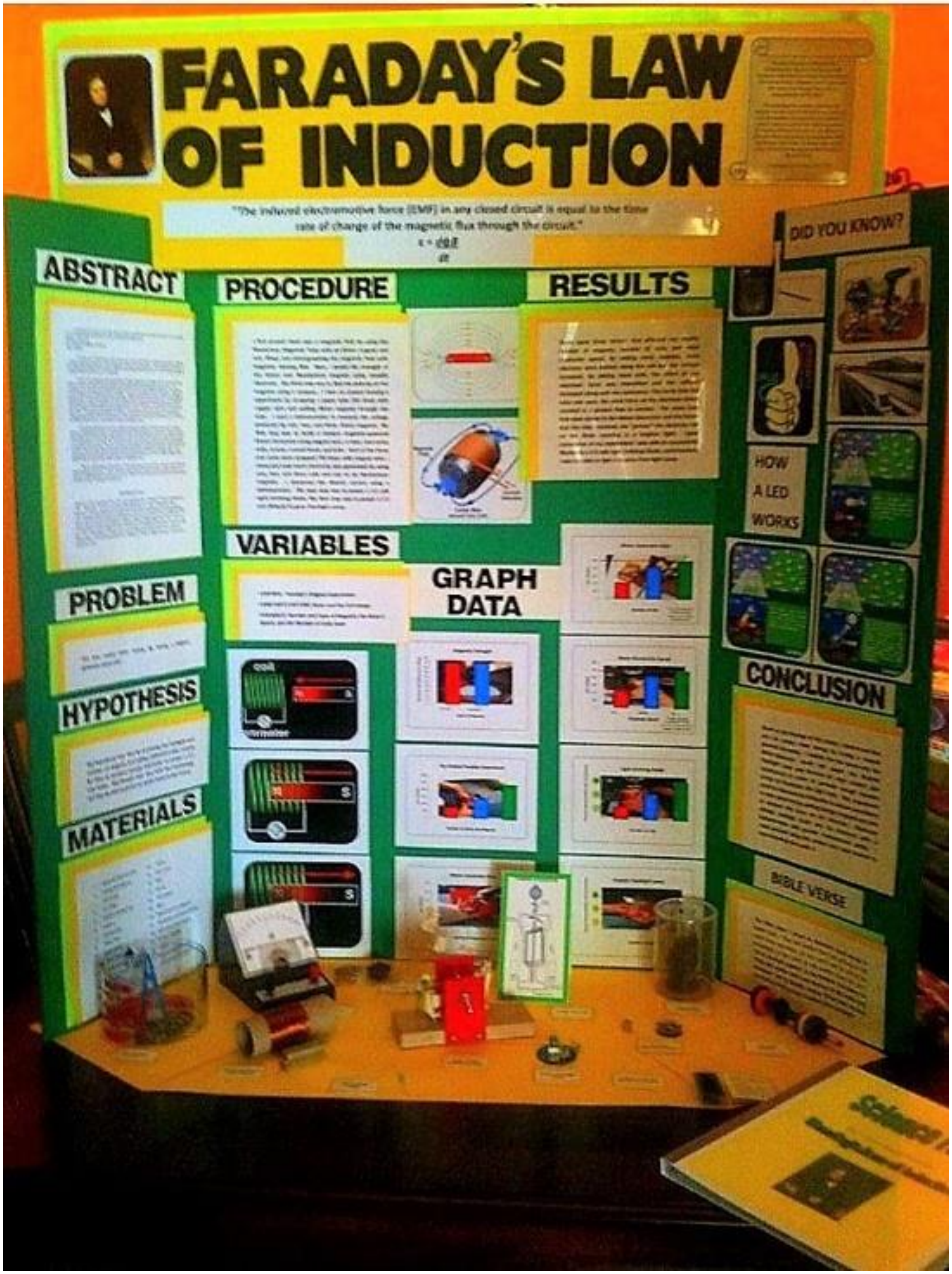
Other (OTH): Studies that cannot be assigned to one of the above subcategories.

Examples & Critiques of Science Fair Boards

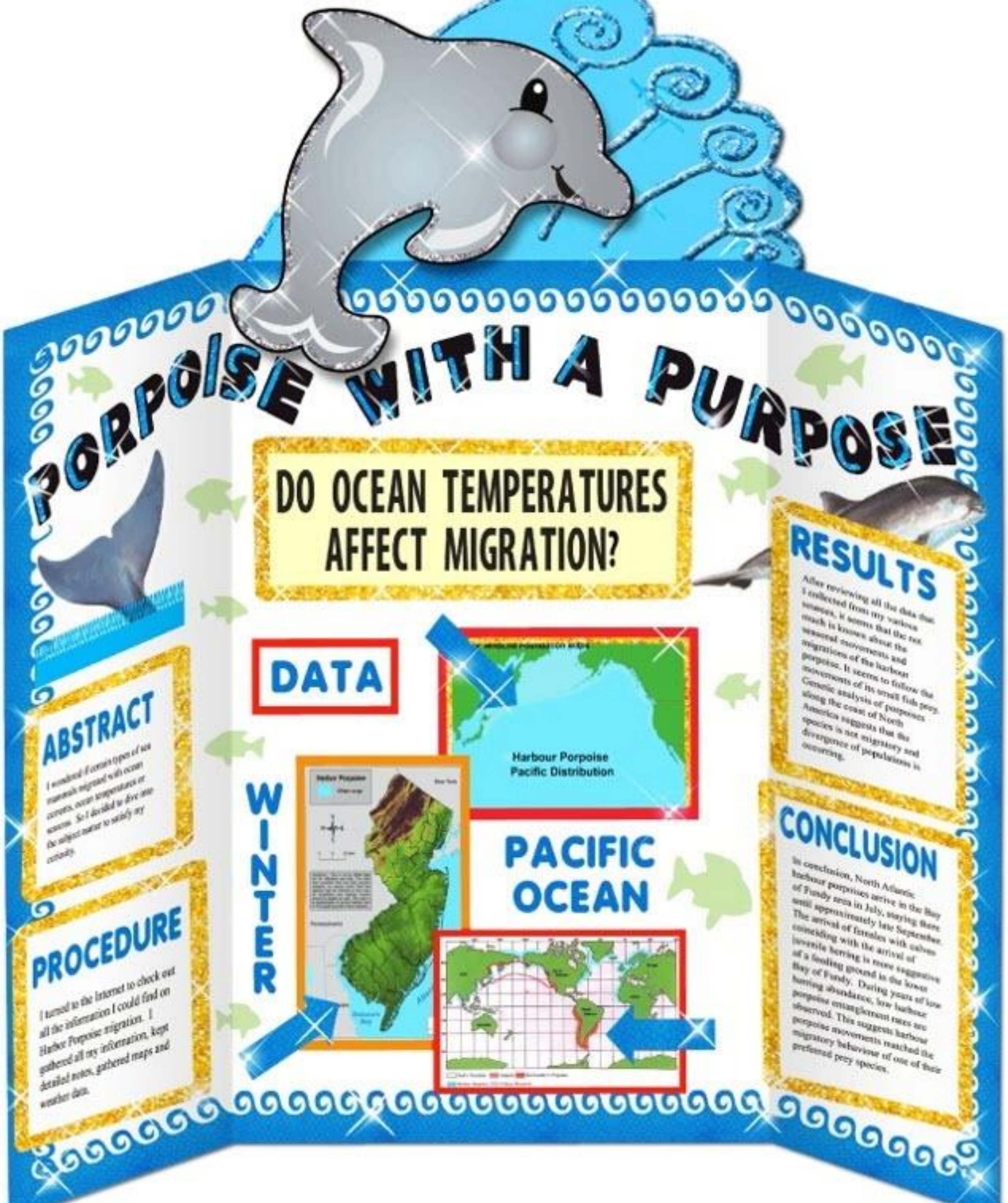
It is difficult to find examples of Engineering project display boards, but the following boards are still good examples of what to do and what not to do.



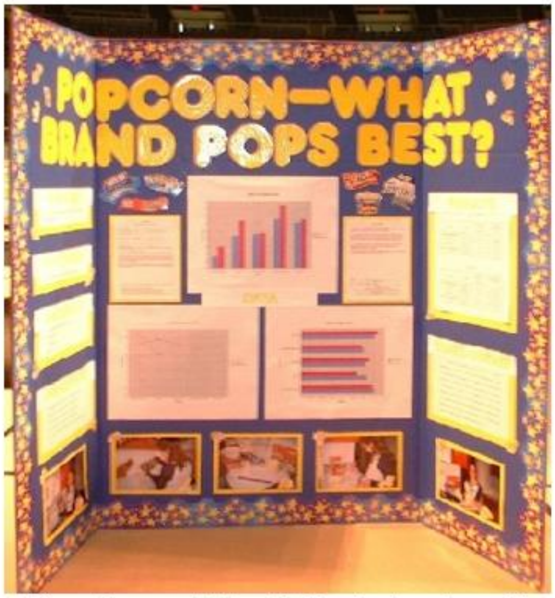
The Materials List must be before the procedure. The graph needs to be before the Results. The metallic border at the top of the board reflects the light and is distracting. The title is catchy.



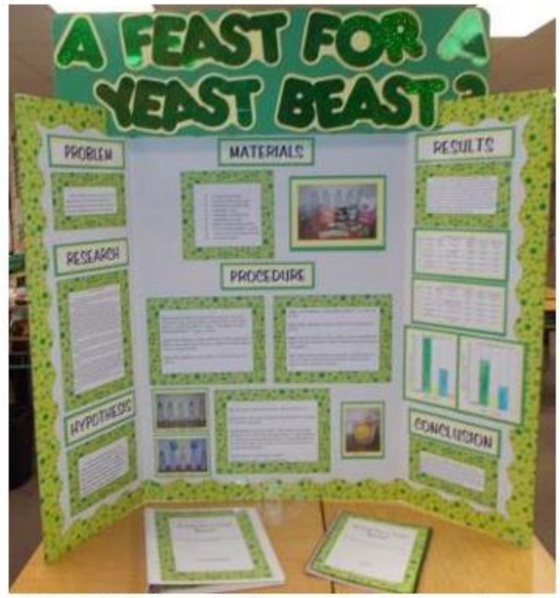
This looks like an Engineering project. Engineering projects do not have a hypothesis or variables.



I think this is a very clever board. The student used 5 colors (blue, red, gold, white and black). The border around the whole board pulls everything together. There too many border colors around the sections of the papers (abstract, procedure, data, etc.)

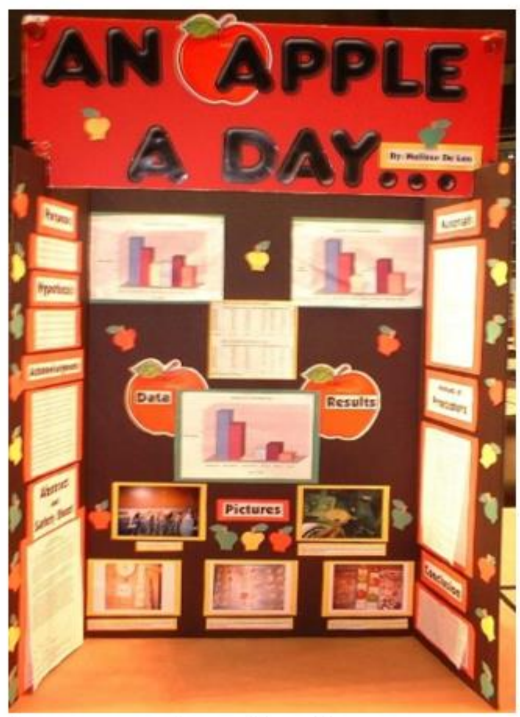


What do you think of this display board?



I love this board. The student stayed with 3 colors. The header is clever. The notebook covers on the table match the borders on the board. It is well organized and easy to follow the headings.

What do you think of this board? Different way of displaying the results.



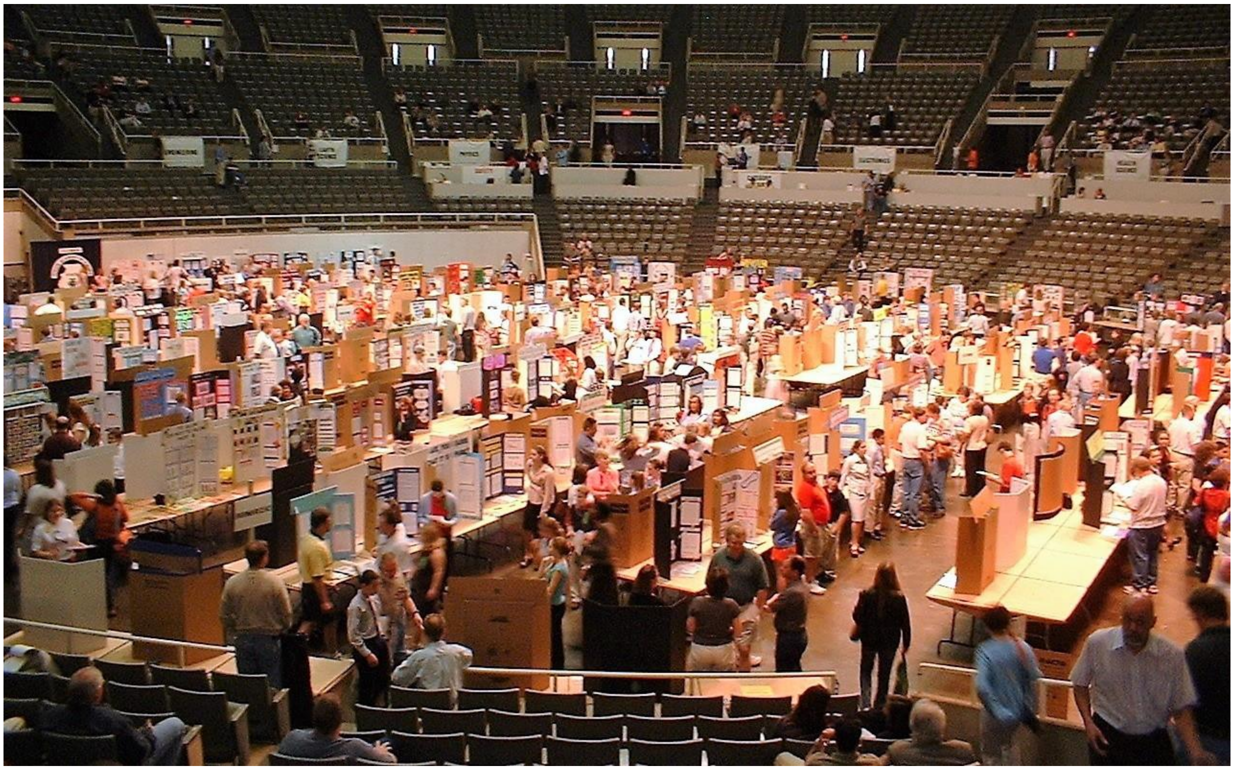
Some more clever ideas here.

What Science Fairs Look Like


INVITED
TO TWO
BIRTHDAYS!


Put

Top/Big Science Fairs



IJAS – Illinois Junior Academy of Science

Intel ISEF

Science Fair Directory

How to Find Science Fairs and Other STEM / STEAM Competitions
There are hundreds of science fairs, engineering fairs, and other STEM competitions held locally, nationally, and internationally every year. Some competitions require students to start at the local level and win in their category to advance to the next level. Other competitions are open to all students. The listings below include both.

Featured STEM Competitions
Affiliated fairs are members of the Society for Science & the Public network. These competitions exist in nearly every state in the U.S. as well as over 70 other countries, regions and territories. Fairs are conducted at local, regional, state and national levels and can be affiliated with the Intel International Science and Engineering Fair (Intel ISEF) and/or the Broadcom MASTERS.

The Intel ISEF is an international pre-college science competition that provides an annual forum for over 1,700 young scientists, engineers and mathematicians from across the world to compete for approximately $4 million in awards. Students in grades 9-12 or equivalent must compete in an Intel ISEF affiliated science fairs around the world and win the right to attend the Intel ISEF. Each affiliated fair may send a predetermined number of projects to the Intel ISEF. Competition begins at the high school level and culminates at the International Science and Engineering Fair, which is usually held in May.

Broadcom MASTERS (Math, Applied Science, Technology and Engineering for Rising Stars) is the premier national science and engineering competition for U.S. middle school students (6th– 8th grade). It aims to encourage engineering and innovation amongst younger students. Society affiliated science fairs around the country nominate the top 10% of 6th, 7th and 8th grade participants to enter this prestigious competition. After submitting the online application, 300 semifinalists are chosen and 30 finalists present their research projects and compete for cash prizes in team hands-on STEM challenges to demonstrate their talents in critical thinking, collaboration, communication and creativity.

Broadcom MASTERS International is a global program that provides 20 middle school students with unique STEM learning experiences. To qualify, students must be nominated from regional fairs.
Deadline: Early April

Fluor Engineering Challenge is an annual K-12 engineering challenge open to students in the U.S. and around the world. The goal is to inspire all students to try their hand at engineering. Materials are low-cost, and the time commitment is short. Participating schools and non-profit organizations are entered in a lottery for cash prizes.

Junior Solar Sprint is an annual model solar car building competition for 5th–8th grade U.S. students. Regional winners go on to compete nationally for prizes.

California Invention Convention is open to K-12 students in California, this competition has students invent their own product, process, or solution to a problem. Local school competitions lead to a state-wide final with prizes.

More Science Fairs, Engineering Fairs and STEM/STEAM Competitions
Conrad Foundation's Spirit of Innovation Challenge is an annual, multi-phase innovation and entrepreneurial competition that aims to attract young innovators and entrepreneurs around the world. It encourages collaborative work with the mission to develop innovative and viable scientific solutions to benefit the world. It challenges high school student teams (age 13-18) to solve real world problems in the areas of Aerospace Exploration & Aviation, Clean Energy & Environment, Cyber Technology & Security, and Health & Nutrition. For students age 13-18. A winning team is awarded $5000 to continue product development. Spirit of Innovation Awards are sponsored, in part, by Lockheed Martin Corporation.
Deadline: 1st week in November
Prize: Seed funding grants, investment opportunities, patent support, business services, scholarships and other opportunities to grow their solution into a real business.

Davidson Fellows Scholarship Program aims to recognize exceptional students and support them in the fulfillment of their potential. It includes categories of science, mathematics, and technology, among others. The top prize is $50,000.

Discovery Young Scientist Challenge (DYSC) is for students in grades 5-8. Ten finalists will receive $1,000 and an all-expenses-paid trip to St. Paul, MN for the competition finals. The first-place winner will receive $25,000.

International BioGENEius Challenge is for high school students only; recognizes outstanding research in biotechnology. Process is state, national, international; hosted by the Biotechnology Institute. Top prize is cash award is in the high 5 figures.

Team America Rocketry Challenge (TARC) is the world's largest model rocket contest, accepts teams of students in grades 7–12 from any U.S. school or non-profit youth organization.

The Junior Science and Humanities Symposia (JSHS) invites high school students in grades 9–12 to conduct an original research investigation in the sciences, engineering, or mathematics, and to participate in a regional symposium sponsored by universities or other academic institutions. Regional winners proceed to a national competition.

Virtual Science Fair
Super Science Fair Projects International Virtual Science Fair Contest / Competition / Olympiad
Elementary through College. All participants will receive an Award Certificate and T-Shirt. A prize is awarded for each of 5 categories. Submit your entry online via email.

Local Science Fairs and More....

The WWW Virtual Library Science Fairs Directory lists Fairs Across the Nation and the World. This Library page is an attempt to provide a single comprehensive list of every science fair accessible through the World Wide Web, whether of global or local scope. Most science fairs in the U.S. and U.S. territories are held from January through March. Fairs outside the U.S. may take place at other times of the year. Students who participate in these fairs must observe the International Rules for Pre-college Science Research.

Regeneron Science Talent Search - MIT THINK Scholars Program is an MIT-led competition promoting STEM (science, technology, engineering and mathematics); it supports and funds projects developed by high school students. Organized by a group of undergraduates at MIT, THINK reaches out to students who have done extensive research on the background of a potential research project and are looking for additional guidance in the early stages of their project. Finalists receive all-expenses paid trips to MIT to attend xFair (MIT's spring tech symposium) and winners receive funding to build their projects.

Maker Faire Maker Faire Bay Area and World Maker Faire New York is an event open to participation by school students, for it is an all-ages gathering of like-minded 'making enthusiasts'; be it tech lovers, crafters, educators, tinkerers, hobbyists, engineers, science clubs, authors, artists, students or commercial exhibitors. Aimed at celebrating arts, crafts, engineering, science projects and the Do-It-Yourself (DIY) mindset, the Faire is an event created by Make: magazine. 'Mini' and 'Featured' are the two types of Faires and both varieties are independently organized but licensed by Maker Media; several editions of both have taken place across the world with the flagship Faires held in Bay Area and New York.
Prize: Increased exposure, experience and engagement with the Maker Faire Education Community which in turn encourages innovation.

Young Scientist Challenge is an engineering competition for young innovators. Students in grades 5-8 are eligible to compete. They are encouraged to provide novel solutions to help solve everyday problems in a 1 to 2-minute video. Winners receive $25,000, and finalists get to work one-on-one with some of 3M's top scientists and engineers. Finalists are announced in June/July and receive an exciting summer of mentoring before the grand prize winner is chosen in October.
Deadline: Mid-late April (challenges posted in December on website)

RoboRAVE International is an open platform, international technology robotics competition. It is ideal for school students. It can feature any robot, using any software and any participant. Eligible teams comprise two to four players, one robot and one coach. The participants can be from elementary, middle or high school students and even Big Kids (which includes University students, teachers, engineers, hobbyists, etc.). Those up to the challenge could compete in a higher division, but they can't take part in multiple divisions of the same challenge.

Challenges vary from building and programming robots that can do the following: complete mazes, climb steep inclined planes, light and extinguish fire without contact, exhibit innovation, win at jousting/ sumo and carry out various tasks despite weighing less than an air vehicle. RoboEthics is a platform where opposing arguments are used to address the ethics of robotics in a global society.

Deadline: Middle of April